Movements of Tagged Lobsters Released off Port Maitland, Nova Scotia, 1944-80

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by

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ABSTRACT

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During the years 1944-68 and 1978-80, a total of 28,226 (about 1000 per year) lobsters (Homarus americanus) were tagged prior to the fishing season (November) and released in a 111-km^2 area off Port Maitland, Nova Scotia. Of the total tags released, 50.1% were recaptured with most (80.8%) of the returns recorded inside the release area and 14.6% within 18.5 km of the release area during the fishing season (≤6 mo of release). There were no differences between size and sex of lobsters in distances traveled. The mean annual straight-line distance between release and recovery for lobsters moving outside the fishing area ranged from 5.2-23.7 km per year. Rayleigh tests demonstrated a non-uniform ($p < 0.05$) distribution of return directions for most years. The main directions of movement were northeast and southeast along the coastline. The few animals (0.2% of total recaptures) which moved >74 km were recaptured mainly in the inshore fisheries of the Bay of Fundy and the Gulf of Maine. The greatest distance (426.6 km) moved was recorded for a 110-mm carapace length male after 13.8 mo at large. Results of this tagging study indicate that commercial-sized lobsters did not, in general, move distances >18.5 km during the December-May intensive fishing season in coastal southwestern Nova Scotia. The tagging study was not designed to monitor long distance movement for periods >6 mo after release because the remaining survivors usually shed their tags during the molting period the following summer after the fishing season.

Key words: Lobster, Homarus americanus, tagging, movements, dispersal

RÉSUMÉ

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De 1944 à 1968 et de 1978 à 1980, un total d'environ 28 226 homards (Homarus americanus) (soit environ 1 000 par année) ont été marqués avant le début de la saison de pêche (novembre) et libérés dans une zone de 111 km^2 au large de Port Maitland, en Nouvelle-Écosse, 50,1% des sujets marqués furent recapturés, la plupart (80,8% des recaptures) à l'intérieur de la zonne de mise en liberté et 14,6% à moins de 18,5 km de cette zone pendant la saison de pêche (≤6 mois de la mise en liberté). Aucune différence n'a été observée entre la taille et le sexe, et la distance parcourue. La distance moyenne annuelle, en ligne droite, entre l'endroit de mise en liberté et celui de la recapture pour les homards capturés hors de la zone de pêche a été de 5,2 à 23,7 km par année. Des tests de Rayleigh ont démontré que, la plupart des années, les déplacements furent surtout en direction du nord-est du sud-ouest le long de la côte. Les quelques sujets (0,2% des recaptures totales) qui se déplacèrent ≤74 km furent recapturés surtout dans les pêcheries côtières de la baie de Fundy et du golfe du Maine. La plus grande distance parcourue (426,6 km) a été par un mâle de longueur de carapace de 110 mm, après 13,8 mois de liberté. Les résultats de ces marquages indiquent que les homards de taille commerciale ne se déplacent pas, en général, à des distances dépassant 18,5 km pendant la saison de pêche intensive qui se pratique de décembre à mai dans les eaux côtières du sud-ouest de la Nouvelle-Écosse. Cette étude ne visait pas à suivre les déplacements du homard sur de grandes distances, pendant des périodes dépassant 6 mois après la mise en liberté, car les survivants perdent généralement leurs marques au moment de la mue, pendant l'été qui suit la saison de pêche.

INTRODUCTION

The coastal waters of southwestern Nova Scotia have traditionally supported a major lobster, Homarus americanus H. Milne-Edwards (Decapoda: Nephropidae), fishery (Stasko and Campbell 1980). To aid in lobster stock assessment, the Port Maitland lobster fishing grounds (Fig. 1) were chosen for permanent study because the locality was considered accessible and representative of the local lobster fishery. For 28 yr (1944-67 and 1978-80) Department of Fisheries and Oceans personnel annually tagged commercial-sized lobsters prior to the fishing season to estimate population sizes, exploitation rates (e.g. Paloheimo 1963), and movement. Although the main purpose of tagging lobsters was to observe the effect of the fishery on the lobster stock, initial analyses on the movement data by Wilder and Murray (1958) and Wilder (1974) indicated that there was little dispersal by the tagged lobsters during the 6-mo fishing season (December 1-May 31). Minimal localized movement of lobsters in coastal waters has also been observed in many other areas, such as Northumberland Strait (Wilder 1963), Maine (Cooper et al. 1975; Krouse 1981), and Rhode Island (Fogarty et al. 1980).

Despite the few summary reports (Wilder and Murray 1958; Wilder 1974; Stasko 1980), there has not been a comprehensive data analysis of the movements of lobsters tagged in the Port Maitland fishery. The purpose of this report is to determine the following: the percentage of tagged lobsters recaptured inside and outside the Port Maitland study area during and subsequent to each fishing season, the direction and distance traveled by lobsters recaptured outside the study area, and if there are differences in distance traveled by different lobster size groups and sexes. As tagged lobsters were released widely throughout the fishing grounds, local small-scale movements were impossible to determine. Therefore, only the direction of movements and distance traveled by lobsters outside the Port Maitland fishing area (Fig. 1) were analyzed. Population size and exploitation rates estimated from these tag release-recapture data will be published elsewhere.

MATERIALS AND METHODS

Lobsters were trapped 1-4 wk (usually November) prior to the start of each fishing season, from 1944-68 and from 1978-80. Approximately 1000 commercial-sized lobsters were measured, sexed, tagged (Table 1), and released uniformly throughout the grounds (ca. 250 lobsters per subarea) each year (see Fig. 1 for size of study area). The monel metal carapace tag (Wilder 1947; Stasko 1980) was used during 1944-68. Both the sphyrion spaghetti tag (Scarratt and Elson 1965) and the monel metal carapace tag were applied to each lobster during 1978 and 1979. Only the sphyrion spaghetti tag was used during 1980 and the growth study in June 1979. To ensure tags were returned with accurate recapture date, location, and depth information, a reward of up to $5 was offered to fishermen; observers were also stationed at several ports to collect the tags and measure recaptured lobsters. Over the many years most fishermen in the SW Nova Scotia area became familiar with the tagging program and were fully aware of the data requirements associated with returning tags.

All measurements of lobsters in this paper are given in millimeters carapace length (CL). Carapace length was measured with Vernier calipers from the inner base of the eye socket to the dorsal posterior margin of the carapace along the mid-line. During 1944-55, however, only the total length of lobsters was measured. Total length (TL) measurements were converted to CL (mm), using the following equations (from Wilder 1953): CL = 0.3744 TL - 5.73 for males, and CL = 0.353 TL - 2.58 TL females. Carapace length measurements were made in 32nd's of an inch until October 1967 and to the nearest millimeter thereafter.

For convenience, the mid-point of each subarea (Fig. 1) was assigned as the release location although ca. 250 tagged lobsters were released uniformly in each subarea. All calculations concerned with distance and direction traveled of tagged lobsters were determined from the latitude and longitude of release subarea mid-points and the approximate recapture locations reported by the fishermen. Lobsters recaptured within the boundary of the whole study area (Fig. 1) were classified as being inside the area irrespective in which subarea the lobsters were released. Each tagged lobster captured outside the boundaries of the whole study area was grouped into one of five classes of distance moved: <18.5 km (1-9 naut mi), 18.5-36.9 km (10-19 naut mi), 37.0-55.5 km (20-29 naut mi), ≥55.6 km (≥30 naut mi), and ≥18.5 km from the mid-point of each subarea of release (Fig. 1). For figures illustrating lobster straight-line movements outside the study area, an approximate mid-point of the whole area (Lat. 43°59', Long. 66°15') was used as the tag release location.

A total of 179 lobsters which had unknown return locations, amounting to 1.25% of total recaptures, was not used in the movement analyses.

A two-way analysis of variance was used to determine the effects of size and sex on distance traveled by recaptured lobsters moving outside the Port Maitland study area. Lobsters were categorized on the basis of release size into classes of 81-94 mm and >94 mm CL, and sex. Because no significant differences ($p > 0.05$) were noted for size, sex, or size-sex interaction for most years, all sizes and sexes were combined for the movement analyses and the data were $\log_{10}X$ transformed prior to analysis.

For an evaluation of the directional components of movement, the following test statistics were computed according to Jones (1959) and Saila and Flowers (1968) with a computer program written in FORTRAN IV for the HP3000 computer:

Mean square dispersion coefficient (km^2/day)

$$a^2 = \frac{1}{n}\left[\sum\frac{r^2}{t} - \frac{(\Sigma r \cos\theta)^2}{\Sigma t}\right]$$

North-south directional component (km/day)

$$V = \frac{\Sigma r \cos\theta}{\Sigma t}$$

East-west directional component (km/day)

$$V' = \frac{\Sigma r \sin\theta}{\Sigma t}$$

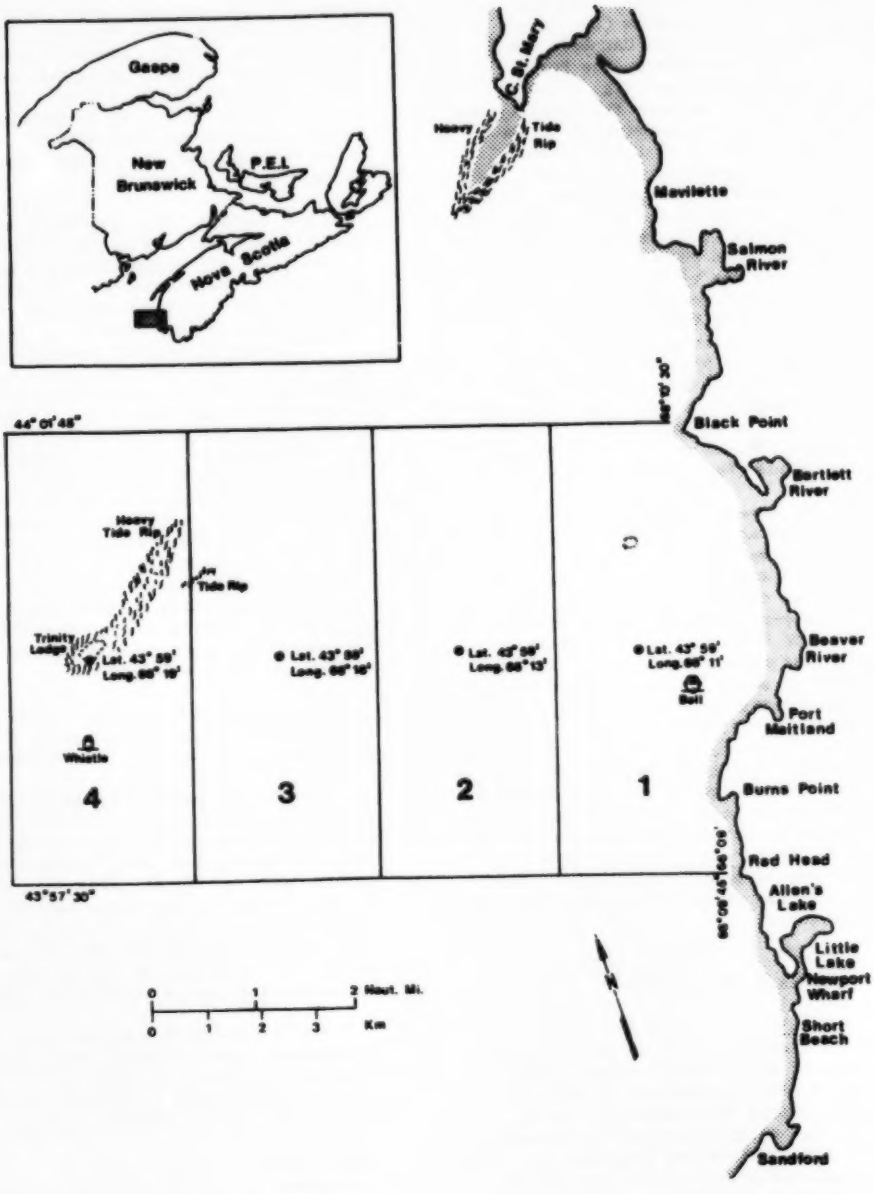

Fig. 1. Traditional lobster fishing area of Port Maitland, southwestern Nova Scotia, arbitrarily subdivided into four subareas. The total fishing area is about 110.9 km^2 (32.3 naut mi^2) at a depth ranging from 7-37 m (4-20 fm). Although tagged lobsters were released uniformly throughout the study area, a mid-point for each of the four subareas is shown (indicated by dot and latitude and longitude on map).

Mean vector angle $\bar{\theta} = \arctan \frac{\Sigma r \sin \theta}{\Sigma r \cos \theta}$

Rayleigh test $Z = R^2/n$

where n = number of individual tag returns;

$R = \sqrt{(\Sigma \sin \theta)^2 + (\Sigma \cos \theta)^2}$;

r = apparent "straight line" distance traveled (km) from release to recapture point;

θ = direction of travel from an arbitrary reference point;

t = time (days) from release to recapture.

All angles (θ) are presented as deviations of true north. The Rayleigh test is a statistical test for randomness or uniform distribution of points about a circle of unit radius (Batschalet 1965). The mean square dispersion coefficient is dependent on both the rate of travel and mean distance traveled and is a measure of undirected or random movement based on physical theories of diffusion and heat conduction (Skellam 1951; Jones 1959). The parameters V and V' indicate the mean rate of directed (non-random) movement of a group of tagged lobsters in the north-south and east-west direction, respectively.

RESULTS

Between 712 and 1032 tagged lobsters (mean size 87.3 mm, range 79-140 mm carapace length; Appendices 1, 2) were released annually during November prior to each fishing season (Table 1). An average of 48.3% tags were returned annually during the first fishing season after each tag release and 1.8% returned thereafter (Table 1). The majority of tags were returned (96.4% of total recaptures) within the first fishing season with only 3.6% recaptured thereafter (Table 1). The percentage tag returns during the first fishing season fluctuated about a mean of 80.8% for those lobsters caught inside the area and 18.1% outside the area (Fig. 2). Although the highest percentage of tagged lobsters moving out of the area was 35.6% during 1968-69 (Fig. 2), the highest percentage of long distance movement (≥18.5 km) of 11.6% occurred during the 1962-63 fishing season (Fig. 3).

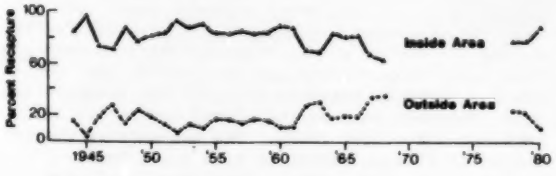

Fig. 2. Yearly percentages of total recaptures of tagged lobsters inside and outside the Port Maitland lobster fishing area (cf. Fig. 1) during the first fishing season after each tag release.

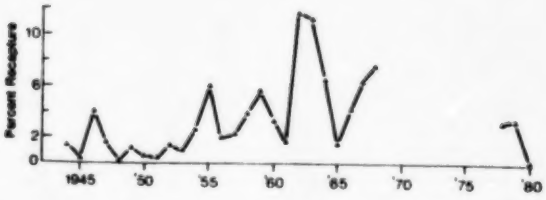

Fig. 3. Yearly percentages of total recaptures of tagged lobsters which moved ≥18.5 km from the Port Maitland fishing area during the first fishing season after each tag release.

The recapture locations provided by fishermen should be considered close approximations. Since the fishing area is not as exact as defined in Fig. 1, the tagged lobsters recaptured <18.5 km and yet outside the area dominated the percentage caught outside the area (Fig. 4), and may still have been subject to local fishing pressure by the fishermen of Port Maitland and adjoining areas. Thus, of the total recaptures (14,270), as much as 92.4% of tags returned were recaptured <18.5 km of the Port Maitland area, indicating most tagged lobsters did not move far.

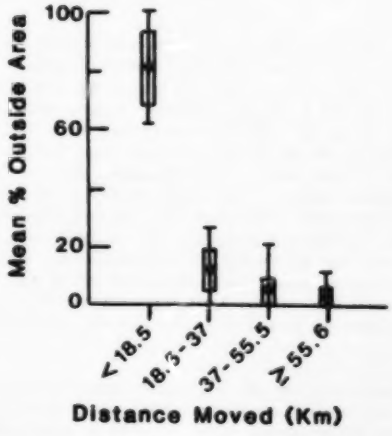

Fig. 4. Mean percentage of tagged lobsters captured outside of Port Maitland area grouped according to 18.5-km classes during 1944-81. The standard error (box) and range (vertical line) are shown about the mean (dot).

Due to intense fishing pressure within the area, most (80.2%) of the tags were returned within the first 6 mo from the time of release (Table 2). The mean days at large for tagged lobsters that moved outside the area was 171 (ca. 6 mo) (Table 2, 3).

The mean straight-line distance tagged lobsters moved outside the Port Maitland area for all years was 15.1 km (±1.28 SE) with little fluctuation between years (range 5.2-23.7 km) (Fig. 5). The maximum distance lobsters moved each year ranged from 20.4 km for the 1948 releases to 426.6 km for the 1966 releases. An exception to this overall mean distance traveled was that of lobsters (mean

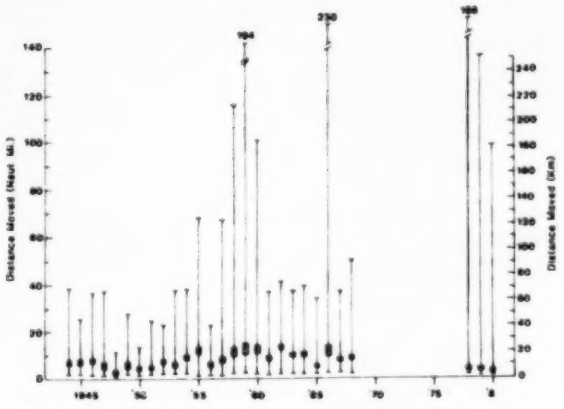

Fig. 5. Mean distance (km) moved for all recaptured tagged lobsters moving out of Port Maitland area grouped according to year of release. The standard error (box) and range (vertical line) are shown about the mean (dot). Numbers at top represent maximum distance moved. Number of tag returns representing each mean are shown in Table 3.

40.4 km ± 8.9 SE, min = 3.34, max = 380.83 km, N=56) released during June 1979 for growth studies. The effect of being released 6 mo prior to the start of the first fishing season allowed tagged lobsters to disperse out of the Port Maitland area before being caught; 60.9% of recaptured tags (N=14) had moved out of the area. The movement details of 30 (0.2%) tagged lobsters recaptured ≥74.1 km (40 naut mi) from the study area for all years (1944-80) are indicated in Table 4 and Fig. 6. A few lobsters crossed the Bay of Fundy to New Brunswick and others were recaptured along the coastline of Maine, U.S.A., with one 110-mm CL male caught 426.6 km from Port Maitland in Oceanographer Canyon, 13.8 mo after release.

Examination of the straight-line tracks between release and recapture points indicated three main directions of movement (Fig. 7, 8): a southeast movement along the coast (150°-180°), a northeast movement along the coast (1°-30°), and a northwest-north movement into the Gulf of Maine and Bay of Fundy (300°-360°) (Fig. 6). These data indicate that some inshore lobsters are capable of extensive movements. Direction statistics (according to Saila and Flowers 1968) were computed for all tagged lobsters that were recaptured outside the Port Maitland area as per each year of release (Table 5). The Rayleigh test statistic, Z, indicated a non-uniform distribution of tag returns ($p < 0.05$) for all years except the 1944-46 and 1949 tag release years. Results of the Rayleigh test should be treated with caution as the data followed a bimodal distribution (Batschalet 1965). In general, the returns exhibited a north-south movement (larger values of V than V', the east-west component). Overall, the mean square dispersion values, a^2, were low, but variable, and difficult to interpret. Higher a^2 values may indicate random dispersal; however, Jones (1959) suggested that these values could be overestimated when there are substantial directional movements and the times at large are short, as in the case of the 35.428 value for 1947-48 (Table 5), where mean time at large was the shortest (97.2 d) (Table 3). The mean vector angle, 0, indicated an average 22° northwest deviation (a 60° angle) and a 40° northeast deviation (a 90° range) from true north. Tagged lobsters generally moved northward and southward (Fig. 7, 8) so that the mean vector angle represents the net northward movement along the coastline. This apparent north-south movement is probably a result of the local high fishing intensity in the inshore southwestern Nova Scotia area during the December-May period each year.

DISCUSSION

The majority of lobsters tagged in this study were of an immature size 74-94 mm CL (Aiken and Waddy 1980). There were insufficient data to indicate sexual differences in movement of large, sexually mature lobsters ≥95 mm CL. Many other tagging experiments conducted on lobsters along the North American Atlantic coast have also shown generally localized lobster movements for both sexes (Wilder 1963; Squires and Ennis 1968; Fogarty et al. 1980; Krouse 1980, 1981; Stasko 1980). However, long-range movements have been recorded for large, sexually mature females which generally tend to move further than equivalent-sized males, especially on offshore areas of the continental shelf (Saila and Flowers 1968; Cooper and Uzmann 1971; Krouse 1980).

The present study indicated the predominant localized movement of immature lobsters tagged and released just prior to the fishing season. Of the 14,270 tags returned, 92.4% moved <18.5 km and only 4.1% were recaptured ≥18.5 km from the Port Maitland fishing area during 1944-81. The results of this study may be biased due to the methods employed which were primarily designed to estimate exploitation rates of local, commercial-sized lobster populations. The limitations in this study for determining lobster movements are as follows: Most (70-80%) of the tagged lobsters were in the immature (79-94 mm CL) size range which appear to move less than mature lobsters (Fogarty et al. 1980). Seasonal inshore-offshore movements of lobsters as indicated by Cooper and Uzmann (1971) and others (c.f. review by Krouse 1980) could not be shown in the present study. The monel metal carapace tags used alone on the majority (83%) of lobsters released off Port Maitland did not stay on most lobsters >9 mo due to molting during June-October (Wilder 1953) which reduced the benefits of monitoring lobster movement over a longer period. Almost half of the lobsters that moved ≥74 km were tagged since 1978 with the sphyrion tag (Table 4) (which is retained through a molt), further indicating the limitation of monitoring long-term movements with monel metal carapace tags. The majority of tagged lobsters were recaptured mainly during the winter months (December-May) of each year when water temperatures are low (1-4°C) and, consequently, lobster activity is lower and lobsters are less catchable than during summer months (11-13°C) (McLeese and Wilder 1958). The non-uniform distribution of fishing effort in both space (most fishermen set traps <37 km from shore) and time (annual fishing season restricted December-May) further complicates the interpretation of the results. The non-uniform sampling effort may bias the samples by causing an apparent directional component to an otherwise possible randomness of lobster movement. During 1944-68 there was no major

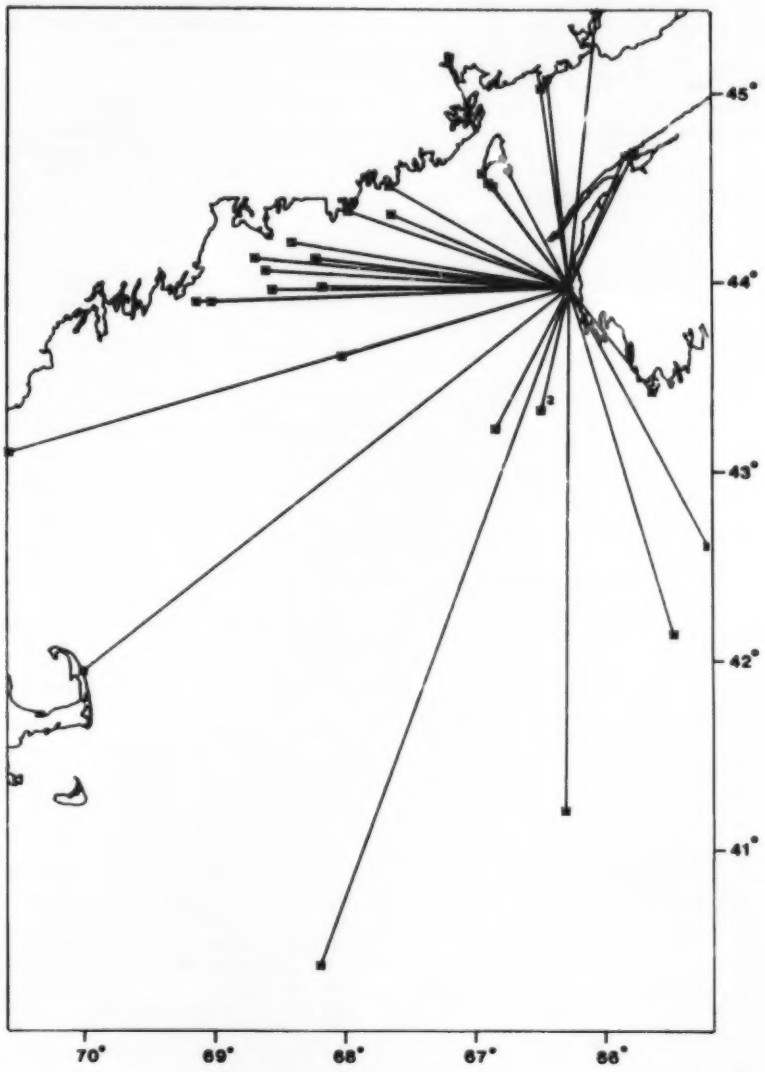

Fig. 6. Map of release and recapture points with straight-line distances traveled for all tagged lobsters recaptured ≥74.1 km from the Port Maitland fishing area (1944-81). One lobster caught at location of each asterisk unless otherwise shown.

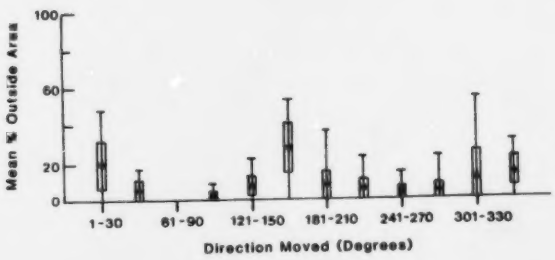

Fig. 7. Mean direction moved by 30° units (of true north, expressed as percentages of total recaptures) of all tagged lobsters recaptured outside the Port Maitland area, 1944-81. The standard error (box) and range (vertical line) are shown about the mean (dot).

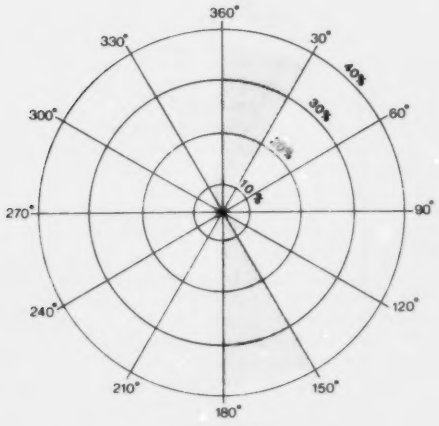

Fig. 8. Mean direction moved by 30° units (of true north, expressed as percentages of total recaptures) of all tagged lobsters recaptured ≥37.0 km from the Port Maitland area, 1944-81.

fishery for lobsters distant from the SW Nova Scotia shore, reducing the chances of detecting long-distance movements. Although commercial lobster fishermen have concentrated their fishing effort mainly in areas of high productivity where lobster densities are highest, they continually place exploratory traps in areas which are usually considered marginal because of high operation costs and low catches per unit of effort. In recent years the lobster fishery has expanded further offshore to areas such as the outer continental shelf (e.g. Georges Bank, Browns Bank, German Bank) (Wilder 1970; Stasko 1978). Thus, it would seem effort distribution would generally approximate most of the lobster distribution in the area at least during 1978-81.

The non-uniform distribution of effort in time (December-May) would thus allow study of lobster movement on a short-term basis mainly during the cold winter period which would limit long-distance movement. Local movement of lobsters, however, has been noted under different experimental conditions. Fogarty et al. (1980) and Krouse (1981) found that movement increased up to 90 d after release and usually leveled off, and that not all tagged lobsters which remained at large for long periods moved great distances. The temporal differences of these latter two studies, such as time of tag releases and seasonality (summer) of the fishery, were unlike that of the Port Maitland tagging study.

The direction recaptured lobsters traveled was primarily northeast and southeast along the Nova Scotia coastline. Any southwest movement offshore probably would not have been detected during 1944-68 due to limited fishing pressure. Krouse (1981), however, also observed a shoreward movement for lobsters moving short distances; he also suggested that lobsters moving ≥37.0 km appeared to travel along with coastal currents. In the present study there was a northward movement along with the prevailing current, but there was also a significant southeast movement by lobsters against currents of the area (Bumpus and Lauzier 1965).

Despite the limitations of this study in determining seasonal changes in lobster movement and the extent of long-distance movement over several years, the data do reveal an important point for population dynamic studies of lobsters in this general area. The data indicate that commercial-sized lobsters do not, in general, move distances >18.5 km during the December-May fishing period in coastal southwestern Nova Scotia. Lack of major lobster movements thus makes the estimation of the size of the local fishable lobster population and exploitation rates slightly less complex.

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Table 1. Summary of percentage recaptures of tagged lobsters off Port Maitland during and after first fishing season following each tag release, 1944-80. A fishing season is approximately 6 mo (December 1-May 31). Only monel metal carapace tags used except where shown.

Year	Release dates	Number of tags released	Total recaptures			% of total releases			% of total recaptures	
			During first season	After first season	All periods	During first season	After first season	All periods	During first season	After first season
1944-45[a]	Dec 6-8, Mar 29-Apr 4	1032	231	39	270	22.38	3.78	26.16	85.56	14.14
1945-56[a]	Nov 28-Dec 5, Mar 16-20	1018	420	25	445	41.26	2.46	43.71	94.38	5.62
1946	Nov 22-Dec 6	998	351	16	367	35.17	1.60	36.77	95.64	4.36
1947	Nov 22-Dec 1	1000	465	32	497	46.50	3.20	49.80	93.56	6.44
1948	Nov 2-9	1000	562	11	573	56.20	1.10	57.30	98.08	1.92
1949	Nov 7-16	1000	517	8	525	51.70	0.80	52.50	98.48	1.52
1950	Nov 2-3	999	433	10	443	43.34	1.00	44.34	97.74	2.26
1951	Nov 1-2	999	513	12	525	51.35	1.20	52.55	97.71	2.29
1952	Nov 4-11	994	607	6	613	61.07	0.60	61.67	99.02	0.98
1953	Nov 2-6	1000	458	3	461	45.80	0.30	46.10	99.35	0.65
1954	Nov 2-3	999	479	3	482	47.95	0.30	48.25	99.38	0.62
1955	Nov 3-5	1000	447	5	452	44.70	0.50	45.20	98.89	1.11
1956	Oct 30-Nov 5	1000	435	6	441	43.50	0.60	44.10	98.64	1.36
1956[b]	Nov 6-8	500	211	2	213	42.20	0.40	42.60	99.06	0.94
1957	Nov 5-15	995	463	8	471	46.53	0.80	47.34	98.30	1.70
1958	Nov 4-17	998	408	18	426	40.88	1.80	42.68	95.77	4.23
1959	Nov 9-13	1000	517	11	528	51.70	1.10	52.80	97.92	2.08
1960	Nov 1-13	998	501	19	520	50.20	1.90	52.10	96.35	3.65
1961	Nov 1-9	1000	489	30	519	48.90	3.00	51.90	94.22	5.78
1962	Nov 2-7	1000	561	17	578	56.10	1.70	57.80	97.06	2.94
1963	Nov 5-7	1000	570	15	585	57.00	1.50	58.50	97.44	2.56
1964	Nov 3-11	1000	549	39	588	54.90	3.90	58.80	93.37	6.63
1965	Nov 8-16	1000	686	26	712	68.60	2.60	71.20	96.35	3.65
1966	Nov 2-9	999	548	32	580	54.86	3.20	58.06	94.48	5.52
1967	Nov 3-10	990	523	9	532	52.83	0.91	53.74	98.31	1.69
1968	Nov 5-12	1000	489	7	496	48.90	0.70	49.60	98.59	1.41
1978[c]	Nov 6-10	996	514	50	564	51.61	5.02	56.63	91.13	8.87
1979[c]	Nov 5-14	999	486	29	515	48.65	2.90	51.55	94.37	5.63
1980[d]	Nov 3-21	712	194	21	215	27.25	2.95	30.20	90.23	9.77
Total/mean		28226	13627	509	14136	48.28	1.80	50.08	96.40	3.60
1979[de]	June 4-13	994	111	23	134	11.17	2.31	13.48	82.84	17.16

[a]Half released during season; [b]Special tagging (Wilder and Murray 1958); [c]Monel and sphyrion tags.
[d]Sphyrion tag only; [e]Growth study.

Table 2. Number (N) and percentage (%) of all tagged lobsters returned at 6-mo intervals after each release year. Tag recaptures with unknown dates excluded.

Year of release	Months at large										Total recaptures (N)
	≤6		7-12		13-18		19-24		>24		
	N	%	N	%	N	%	N	%	N	%	
1944	229	85.13	15	5.58	24	8.92	0	0.00	1	0.37	269
1945	419	94.58	2	0.45	19	4.29	0	0.00	3	0.68	443
1946	323	95.28	0	0.00	10	2.95	0	0.00	6	1.77	339
1947	448	92.18	10	2.06	26	5.35	1	0.21	1	0.21	486
1948	501	87.59	61	10.66	3	0.52	1	0.17	6	1.05	572
1949	404	78.14	105	20.31	7	1.35	0	0.00	1	0.19	517
1950	338	76.47	94	21.27	9	2.04	0	0.00	1	0.23	442
1951	423	83.60	72	14.23	4	0.79	3	0.59	4	0.79	506
1952	554	90.97	49	8.05	4	0.66	2	0.33	0	0.00	609
1953	368	80.52	88	19.26	0	0.00	0	0.00	1	0.22	457
1954	398	83.09	79	16.49	0	0.00	2	0.42	0	0.00	479
1955	370	82.04	76	16.85	4	0.89	1	0.22	0	0.00	451
1956	335	76.31	97	22.10	7	1.59	0	0.00	0	0.00	439
1956[a]	190	89.20	21	9.86	1	0.47	1	0.47	0	0.00	213
1957	404	85.77	59	12.53	6	1.27	1	0.21	1	0.21	471
1958	337	79.67	69	16.31	15	3.55	1	0.24	1	0.24	423
1959	425	81.42	87	16.67	9	1.72	0	0.00	1	0.19	522
1960	411	79.50	87	16.83	8	1.55	9	1.74	2	0.39	517
1961	339	67.40	139	27.63	19	3.78	6	1.19	0	0.00	503
1962	375	71.29	138	26.24	12	2.28	1	0.19	0	0.00	526
1963	403	73.41	132	24.04	12	2.19	2	0.36	0	0.00	549
1964	435	74.36	113	19.32	31	5.30	4	0.68	2	0.34	585
1965	598	85.92	71	10.20	22	3.16	4	0.58	1	0.14	696
1966	401	72.12	124	22.30	22	3.96	9	1.62	0	0.00	556
1967	403	76.62	115	21.86	3	0.57	4	0.76	1	0.19	526
1968[b]	366	75.00	113	23.16	8	1.64	0	0.00	1	0.20	488
1978[b]	375	66.85	139	24.78	36	6.42	8	1.43	3	0.53	561
1979[c]	369	74.24	101	20.32	21	4.22	3	0.61	3	0.61	497
1980[c]	169	78.60	26	12.09	17	7.91	3	1.39	0	0.00	215
Total/mean	11,110	80.18	2,282	16.47	359	2.59	66	0.48	40	0.29	13,857
1979[cd]	15	11.63	91	70.54	4	3.10	16	12.40	3	2.33	129

[a]Special tagging (Wilder and Murray 1958).
[b]Monel and sphyrion tags.
[c]Sphyrion tag only.
[d]Growth study.

Table 3. Mean days at large between release and recapture of tagged lobsters caught outside the Port Maitland release area (SE = ± 1 standard error).

Year	Mean	SE	Number
1944	176.4	55.5	41
1945	267.0	49.3	26
1946	185.9	24.6	70
1947	97.2	9.8	136
1948	147.9	24.2	77
1949	104.6	9.6	125
1950	163.4	20.1	80
1951	161.5	32.2	72
1952	145.5	16.5	40
1953	143.9	8.3	47
1954	181.8	10.7	45
1955	154.5	10.5	73
1956	142.4	8.1	73
1956[a]	107.3	14.9	21
1957	185.1	15.6	69
1958	213.0	22.5	75
1959	177.2	10.7	88
1960	253.4	25.7	66
1961	203.8	19.4	74
1962	142.1	9.5	167
1963	137.2	7.4	191
1964	216.9	16.3	122
1965	163.3	10.8	148
1966	178.0	13.8	122
1967	164.6	8.4	183
1968	140.8	6.5	181
1978[b]	190.8	15.6	135
1979[b]	156.5	14.2	120
1980[c]	263.1	40.7	22
Mean	171.2	9.6	29
1979[cd]	373.6	28.3	56

[a]Special tagging (Wilder and Murray 1958).
[b]Monel and sphyrion tags.
[c]Sphyrion tag only.
[d]Growth study.

Table 4. Movement information on individual tagged lobsters recaptured ≥74.1 km (40 naut mi) from the Port Maitland study area. M = male, F = female, Size = carapace length (mm).

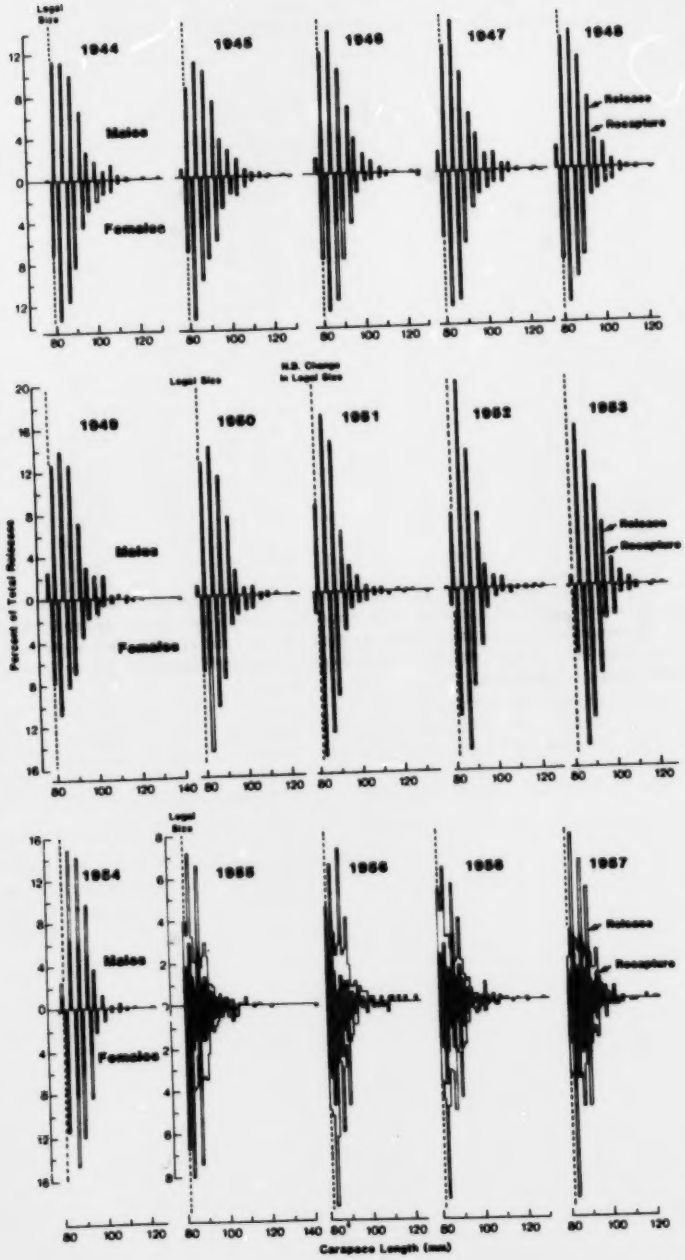
Tag number	Release date	Release Size	Release Sex	Release location Lat.	Release location Long.	Recapture date	Recapture location Lat.	Recapture location Long.	Months out	Distance moved km	Direction moved degrees
56615	04/11/55	108	M	43°59'	66°16'	22/05/56	44°31'	67°38'	6.5	123.9	298.6
56114	05/11/55	107	M	43 59	66 11	31/03/56	44 31	66 50	4.8	78.8	318.9
67341	06/11/57	87	M	43 59	66 13	08/06/58	45 05	66 25	6.9	123.4	352.6
72023	04/11/58	105	F	43 59	66 11	13/04/59	44 08	68 12	5.2	162.0	275.9
72808	05/11/58	91	M	43 59	66 19	23/04/59	44 35	66 55	5.4	82.1	324.4
72871	05/11/58	103	M	43 59	66 19	08/06/59	43 54	69 00	6.9	215.0	267.5
76926	09/11/59	102	M	43 59	66 19	25/05/60	44 36	66 43	6.4	75.6	335.1
76615	10/11/59	107	F	43 59	66 16	06/07/60	43 06	70 33	7.7	359.0	254.1
76680	11/11/59	111	M	43 59	66 16	19/05/60	45 02	66 28	6.2	117.9	352.3
80102	03/11/60	92	M	43 59	66 11	17/06/61	44 32	66 52	7.3	81.9	318.3
80682	12/11/60	105	M	43 59	66 16	12/11/62	44 04	68 35	24.0	185.3	272.9
88909	07/11/62	87	M	43 59	66 19	01/05/63	44 35	65 53	5.8	75.1	27.3
1424	02/11/66	87	F	43 59	66 13	01/06/67	45 35	66 01	6.8	178.6	5.1
1776	07/11/66	110	M	43 59	66 19	08/01/68	40 24	68 10	13.8	426.6	200.9
1624	08/11/66	91	M	43 59	66 16	Unknown	44 41	65 49	Unknown	85.6	24.7
7912	06/11/68	86	M	43 59	66 19	23/06/69	44 42	65 45	7.4	91.5	29.5
13024	07/11/78	103	F	43 59	66 19	01/05/79	43 14	66 49	5.8	92.7	205.8
13370	08/11/78	83	F	43 59	66 15	23/05/80	44 22	67 37	18.2	117.0	291.4
13617	09/11/78	91	F	43 59	66 13	12/08/80	44 13	68 23	20.7	175.0	278.5
13542	09/11/78	83	M	43 59	66 13	29/11/79	43 26	65 37	12.4	77.8	141.7
13535	09/11/78	89	F	43 59	66 15	17/06/81	41 13	66 17	30.7	307.6	180.5
17184	05/06/79	89	M	43 59	66 19	16/06/80	42 09	65 27	12.2	215.7	160.9
17404	06/06/79	113	M	43 59	66 15	Unknown	43 59	68 09	Unknown	152.0	270.0
17541	08/06/79	81	F	43 59	66 13	09/01/80	42 37	65 11	7.0	173.5	151.2
17654	11/06/79	86	M	43 59	66 15	15/03/81	43 20	66 28	20.8	74.3	193.6
17788	11/06/79	93	M	43 59	66 15	13/08/80	43 54	69 07	13.9	229.6	267.7
29319	07/11/79	107	F	43 59	66 19	10/10/80	44 08	68 40	10.9	188.5	275.1
29854	13/11/79	88	M	43 59	66 11	26/05/82	43 37	68 00	29.9	151.4	254.4
38365	15/11/80	95	F	43 59	66 15	15/09/81	44 23	67 57	9.8	142.7	288.2
38421	17/11/80	86	M	43 59	66 15	01/06/82	43 58	68 32	18.1	142.7	269.4

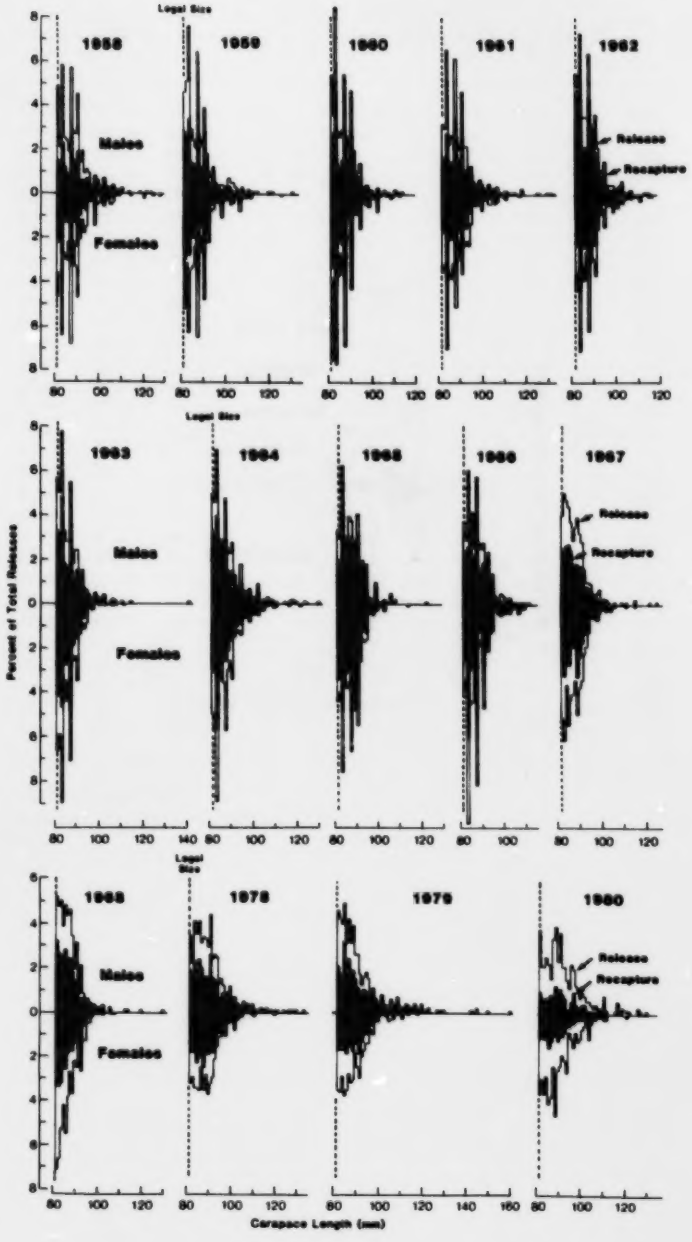
Table 5. Direction statistics for tagged lobsters recaptured outside Port Maitland release area during all periods, 1944-68, 1978-80. $\bar{\theta}$ = mean vector angle from true north; a^2 = mean square dispersion coefficient is a measure of random movements; V and V' = non-random directed movement along north-south and east-west plane, respectively, negative values of V and V' indicate net southerly and westerly movement, respectively; R and Z = Rayleigh test statistics for randomness or uniform distribution of points about a circle; N = number of individuals; ** = significant at $p < 0.01$ and * = significant at $p < 0.05$ indicate a non-uniform distribution.

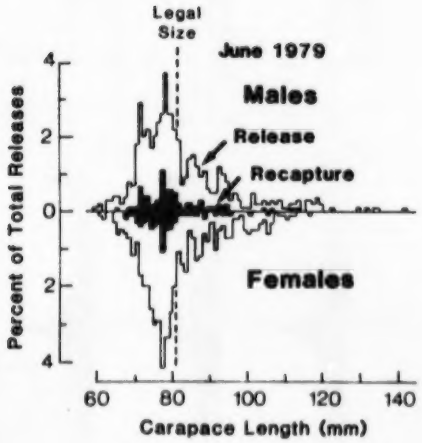
Year	$\bar{\theta}$	a^2 (km^2/d)	V (km/d)	V' (km/d)	R	Z	N
1944	81.92	4.735	0.0015	0.0103	8.8747	1.8316	43
1945	20.47	1.694	0.0154	0.0058	6.1788	1.4684	26
1946	45.69	3.072	0.0112	0.0114	11.4925	1.8868	70
1947	348.33	35.428	0.0647	-0.0134	82.6051	49.8073**	137
1948	303.56	0.366	0.0089	-0.0134	35.7440	16.5926**	77
1949	9.43	4.814	0.0458	0.0076	1.2593	0.0127	125
1950	330.54	0.293	0.0288	-0.0163	63.3915	50.2310**	80
1951	340.65	0.734	0.0152	-0.0054	23.6159	7.7460**	72
1952	34.52	1.587	0.0199	0.0137	11.7014	3.4231*	40
1953	86.99	1.332	0.0007	0.0134	14.2318	3.5534*	57
1954	38.89	2.043	0.0218	0.0176	13.3055	3.9341*	45
1955	358.92	4.909	0.0619	-0.0012	28.4176	11.0625**	73
1956[a]	12.55	0.611	0.0469	0.0105	14.8040	10.4361**	21
1956	15.52	1.064	0.0309	0.0086	15.6690	3.3632*	73
1957	11.54	2.677	0.0469	0.0096	30.3522	13.3516**	69
1958	328.74	7.601	0.0277	-0.0168	19.6528	5.1498**	75
1959	354.28	10.297	0.0192	-0.0019	20.7615	4.8431**	89
1960	352.03	3.306	0.0421	-0.0059	27.7414	11.6604**	66
1961	86.69	1.778	0.0009	0.0172	17.6912	4.2294*	74
1962	35.63	6.718	0.0489	0.0350	40.5555	9.8488**	167
1963	329.75	4.848	-0.0491	0.0286	93.0506	45.3320**	191
1964	33.54	5.535	0.0258	0.0171	20.9102	3.5840*	122
1965	332.98	0.972	-0.0234	0.0119	92.2736	57.5298**	148
1966	336.68	8.086	-0.0213	0.0092	53.6817	23.6207**	122
1967	74.60	3.821	0.0020	0.0074	37.0167	7.4876**	183
1968[b]	342.90	8.814	-0.0544	0.0167	96.4731	51.4202**	181
1978[b]	20.39	3.923	-0.0598	-0.0223	98.1222	70.7939**	136
1979[b]	21.18	5.009	-0.0664	-0.0257	78.9039	51.8819**	120
1979[cd]	22.46	10.732	-0.0614	-0.0254	28.4689	14.2189**	57
1980[c]	82.89	6.291	-0.0075	-0.0605	11.1093	5.6099**	22

[a]Special tagging (Wilder and Murray 1958).
[b]Monel and sphyrion tags.
[c]Sphyrion tag only.
[d]Growth study.

Appendix 1. Graphs showing size frequencies of all tagged male and female lobsters released and recaptured off Port Maitland for each release year, 1944-80. Frequencies expressed as percentage of total tag releases for each year. See Appendix 2 for numbers and mean carapace lengths of released and recaptured tagged lobsters.


Legal Size
1944
1945
1946
1947
1948
Males
Females
Release
Recapture
N.B. Change in Legal Size
1949
1950
1951
1952
1953
Percent of Total Release
1954
1955
1956
1956
1957
Carapace Length (mm)


Legal Size
1958
1959
1960
1961
1962
Males
Females
Release
Recapture
1963
1964
1965
1966
1967
1968
1978
1979
1980
Percent of Total Release
Carapace Length (mm)


Legal
Size
June 1979
Males
Release
Recapture
Females
Percent of Total Releases
4
2
0
2
4
60
80
100
120
140
Carapace Length (mm)

Appendix 2A. Mean carapace length (mm) of tagged lobsters released in Port Maitland area. M = males, F = females, T = totals, SE = ± 1 standard error.

Year	Carapace length (mm)										
	Mean			SE			Max. size		Number		
	M	F	T	M	F	T	M	F	M	F	T
1944	87.8	87.3	87.5	0.3	0.3	0.2	129	114	488	543	1031
1945	88.7	87.5	88.1	0.4	0.3	0.2	125	128	491	527	1018
1946	87.0	86.3	86.6	0.3	0.3	0.2	125	125	501	497	998
1947	87.1	87.2	87.1	0.3	0.3	0.2	122	125	520	480	1000
1948	86.5	86.3	86.4	0.3	0.3	0.2	114	121	519	481	1000
1949	87.3	86.7	87.0	0.3	0.4	0.2	118	139	574	426	1000
1950	86.5	86.1	86.3	0.3	0.3	0.2	122	110	521	478	999
1951	87.3	87.0	87.2	0.3	0.3	0.2	125	132	517	482	999
1952	87.1	87.4	87.3	0.3	0.3	0.2	122	121	525	469	994
1953[a]	89.9	89.5	89.7	0.4	0.4	0.3	122	117	247	252	499
1954	88.6	87.9	88.3	0.2	0.2	0.2	122	110	491	508	999
1955	87.2	87.2	87.2	0.3	0.3	0.2	115	142	448	551	999
1956	87.3	87.0	87.1	0.3	0.2	0.2	129	122	467	533	1000
1956[b]	87.7	86.2	86.9	0.4	0.3	0.3	122	109	232	268	500
1957	87.9	87.3	87.6	0.3	0.2	0.2	122	112	480	515	995
1958	88.5	88.2	88.4	0.3	0.3	0.2	123	127	472	526	998
1959	87.7	87.8	87.7	0.3	0.3	0.2	130	125	501	499	1000
1960	86.7	86.5	86.6	0.2	0.2	0.2	113	112	484	514	998
1961	88.8	87.8	88.3	0.3	0.2	0.2	130	116	491	509	1000
1962	86.8	87.2	87.0	0.2	0.3	0.2	114	115	519	480	999
1963	86.3	85.7	86.0	0.3	0.2	0.2	140	111	459	541	1000
1964	87.8	86.9	87.3	0.3	0.2	0.2	129	121	469	531	1000
1965	87.4	86.9	87.1	0.3	0.2	0.2	121	113	440	560	1000
1966	87.1	86.9	87.0	0.2	0.2	0.2	110	108	446	553	999
1967	87.0	86.8	86.9	0.3	0.2	0.2	124	114	460	530	990
1968	86.6	86.0	86.3	0.2	0.2	0.2	129	107	479	519	998
1978	90.2	88.4	89.4	0.4	0.3	0.2	132	119	542	455	997
1979	90.3	88.4	89.5	0.5	0.3	0.3	159	117	550	436	986
1979[c]	82.1	80.5	81.3	0.6	0.5	0.4	141	116	506	489	995
1980	91.7	89.3	90.5	0.5	0.4	0.3	129	120	353	359	712

[a]Not all lobsters measured.
[b]Special tagging (Wilder and Murray 1958).
[c]Growth study.

Appendix 2B. Mean carapace length (mm) of recaptured lobsters tagged off Port Maitland. Measurements of carapace length made at release assuming no growth had occurred. M = males, F = females, T = totals, SE = ± 1 standard error.

	Carapace length (mm)										
	Mean			SE			Max. size		Number		
Year	M	F	T	M	F	T	M	F	M	F	T
1944	89.1	88.0	88.5	0.7	0.6	0.5	114	110	114	155	269
1945	89.2	88.4	88.8	0.5	0.5	0.4	114	117	208	337	445
1946	87.4	86.6	87.0	0.5	0.5	0.4	114	125	175	192	367
1947	87.5	86.9	87.2	0.5	0.4	0.3	122	110	261	237	498
1948	87.1	85.9	86.5	0.4	0.4	0.3	114	121	290	283	573
1949	89.0	86.8	88.0	0.5	0.5	0.4	118	139	302	223	525
1950	86.1	86.4	86.2	0.4	0.4	0.3	114	107	225	218	443
1951	87.0	87.2	87.1	0.4	0.4	0.3	118	132	262	263	525
1952	87.2	87.5	87.3	0.3	0.3	0.2	118	114	298	315	613
1953[a]	89.7	89.2	89.5	0.6	0.6	0.4	122	110	131	116	247
1954	88.1	87.9	88.1	0.3	0.3	0.2	107	107	219	263	482
1955	87.1	87.1	87.1	0.4	0.4	0.3	109	121	201	251	452
1956	87.1	87.2	87.2	0.4	0.4	0.3	129	115	206	235	441
1956[b]	87.6	85.6	86.5	0.8	0.4	0.4	122	102	95	118	213
1957	87.9	87.2	87.5	0.4	0.3	0.2	122	112	213	258	471
1958	88.9	87.9	88.4	0.5	0.4	0.3	118	120	204	222	426
1959	87.6	87.6	87.6	0.4	0.4	0.3	121	111	255	273	528
1960	86.6	86.6	86.6	0.3	0.3	0.2	111	112	247	273	520
1961	88.7	87.5	88.1	0.4	0.3	0.3	129	109	253	266	519
1962	86.6	86.8	86.7	0.3	0.3	0.2	106	110	302	276	578
1963	86.5	85.8	86.1	0.4	0.2	0.2	140	107	272	313	585
1964	87.3	87.0	87.2	0.4	0.3	0.2	123	116	283	304	587
1965	87.8	87.0	87.3	0.3	0.2	0.2	121	102	304	408	712
1966	87.2	86.8	87.0	0.3	0.3	0.2	110	106	241	339	580
1967	86.5	86.8	86.6	0.3	0.3	0.2	108	103	251	281	532
1968	86.5	85.8	86.1	0.4	0.3	0.2	129	102	246	250	496
1978	90.1	88.7	89.5	0.4	0.4	0.3	125	119	298	266	564
1979	90.1	88.6	89.4	0.5	0.4	0.3	144	107	281	234	515
1979[c]	80.2	78.1	79.2	1.2	1.0	0.8	113	105	70	64	134
1980	91.7	88.9	90.2	0.9	0.6	0.5	126	111	101	114	215

[a]Not all lobsters measured.
[b]Special tagging (Wilder and Murray 1958).
[c]Growth study.

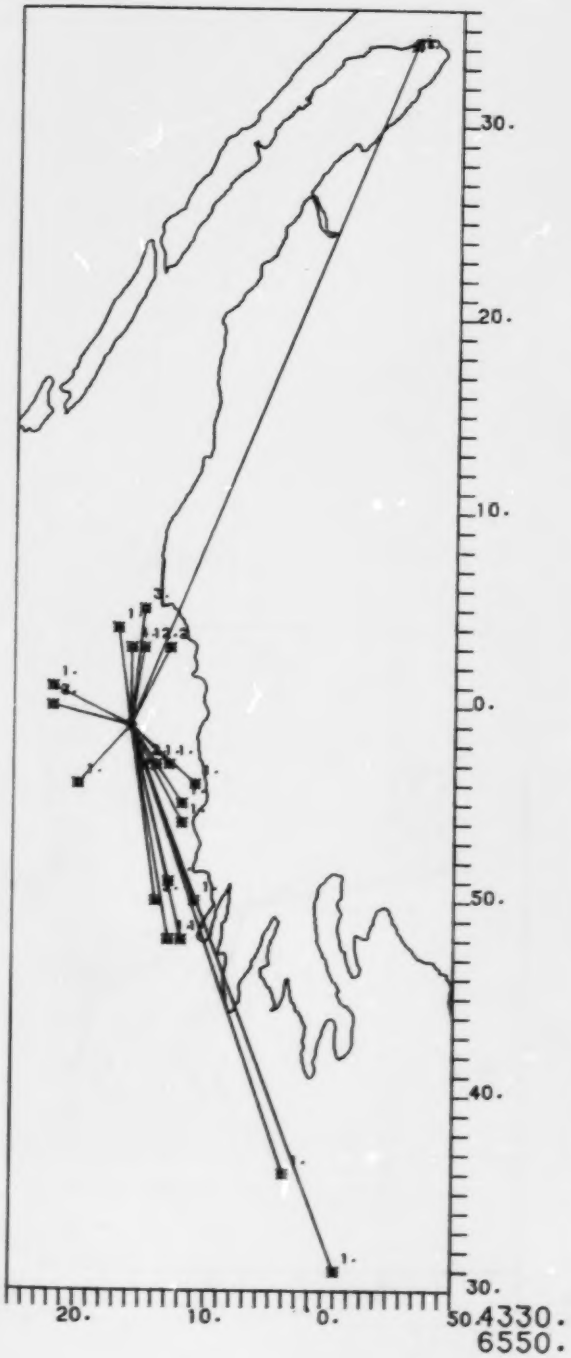
Appendix 2C. Mean carapace length (mm) of recaptured lobsters moving out of Port Maitland area. Measurements of carapace length made at release assuming no growth had occurred. M = males, F = females, T = totals, SE = ± 1 standard error.

Year	Carapace length (mm)										
	Mean			SE			Max. size		Number		
	M	F	T	M	F	T	M	F	M	F	T
1944	87.4	86.4	86.8	1.3	1.2	0.9	99	103	17	25	42
1945	92.5	87.8	90.2	2.8	2.3	1.8	114	110	13	13	26
1946	86.8	87.7	87.2	1.0	2.0	0.9	103	125	44	26	70
1947	87.4	86.2	86.8	1.0	0.8	0.6	110	110	67	70	137
1948	86.7	85.6	86.1	1.3	1.1	0.8	110	107	38	39	77
1949	88.6	87.6	88.2	0.9	1.4	0.8	114	139	73	52	125
1950	84.2	84.9	84.5	0.6	1.0	0.6	92	100	42	38	80
1951	89.0	87.6	88.3	1.7	1.0	0.9	118	114	32	40	72
1952	88.5	86.8	87.7	1.2	1.9	1.1	103	114	22	18	40
1953[a]	89.6	93.5	91.0	1.2	1.9	1.0	107	110	30	17	47
1954	89.3	87.5	88.6	1.0	1.2	0.8	99	100	26	19	45
1955	89.5	88.6	89.1	1.2	1.3	0.9	108	121	35	38	73
1956	87.1	84.6	85.7	1.6	1.1	1.0	95	94	9	12	21
1956[b]	87.2	87.3	87.2	0.7	1.2	0.7	101	115	39	34	73
1957	87.8	88.4	88.1	0.8	1.2	0.7	102	110	37	32	69
1958	89.3	89.7	89.5	1.1	1.3	0.8	105	120	37	38	75
1959	89.6	88.2	89.0	1.2	1.3	0.9	114	109	52	37	89
1960	87.1	88.9	87.9	1.0	1.6	0.9	105	112	38	28	66
1961	88.8	88.2	88.5	0.9	0.7	0.6	103	99	39	35	74
1962	87.7	87.1	87.5	0.5	0.6	0.4	105	110	104	63	167
1963	86.7	86.5	86.6	0.6	0.5	0.4	106	106	96	95	191
1964	87.4	87.8	87.6	0.7	0.8	0.5	103	116	66	56	122
1965	88.3	87.8	88.0	0.7	0.5	0.4	107	98	59	89	148
1966	89.3	88.1	88.6	0.8	0.7	0.5	110	106	50	72	122
1967	87.1	87.6	87.4	0.6	0.5	0.4	102	103	77	106	183
1968	86.1	85.9	86.0	0.5	0.5	0.3	100	102	84	97	181
1978	90.5	89.7	90.0	0.8	0.7	0.5	104	110	52	77	129
1979	84.0	79.2	81.9	2.1	1.7	1.4	113	100	29	22	51
1979[c]	91.9	90.9	91.5	1.1	0.8	0.7	118	107	64	51	115
1980	91.7	91.8	91.7	3.9	2.8	2.3	121	111	10	12	22

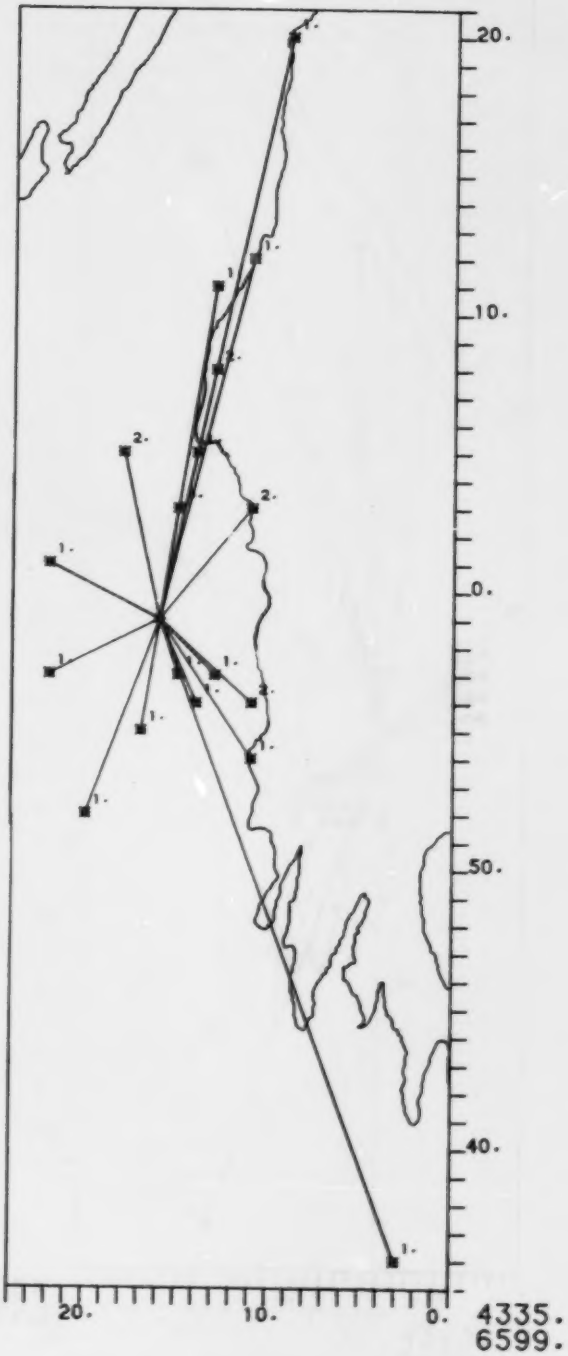
[a]Not all lobsters measured.
[b]Special tagging (Wilder and Murray 1958).
[c]Growth study.

Appendix 3. Maps of release and recapture points with apparent straight-line distances traveled for all tagged lobsters recaptured outside the Port Maitland fishing area for each release year (1944-80). Numbers beside asterisks indicate numbers of lobsters recaptured at each location. Latitude and longitude indicated outside of squares (bottom right). Arrows indicate recaptures beyond map with distance traveled (km) beside the arrow. Data for some years are split into two maps when there are too many data points: one map with recaptures <10 naut mi (<18.5 km) and the other map for the same year with recaptures ≥10 naut mi (≥18.5 km).

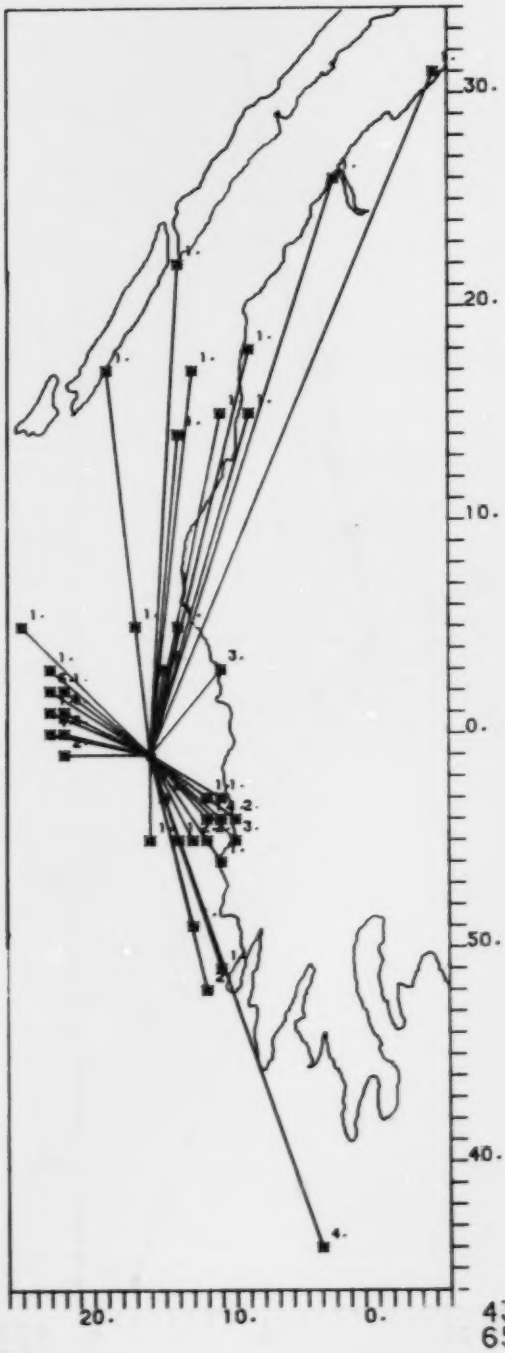
1944


30.
20.
10.
0.
50.
40.
30.
20.
10.
0.
50.
4330.
6550.

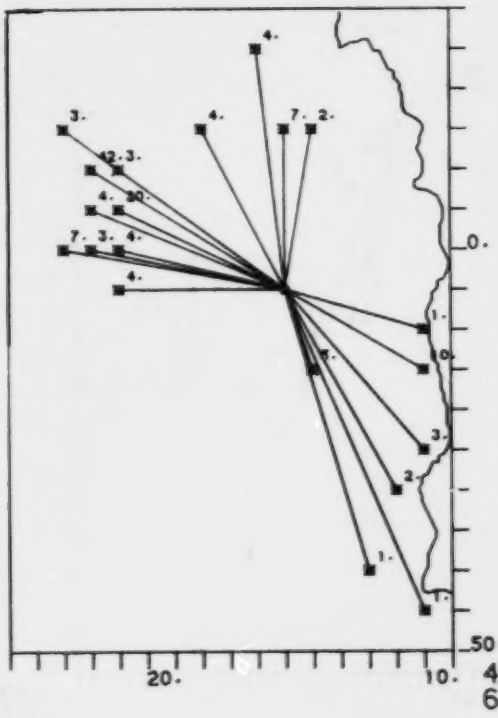
1945


20.
10.
0.
50.
40.
20.
10.
0.
4335.
6599.

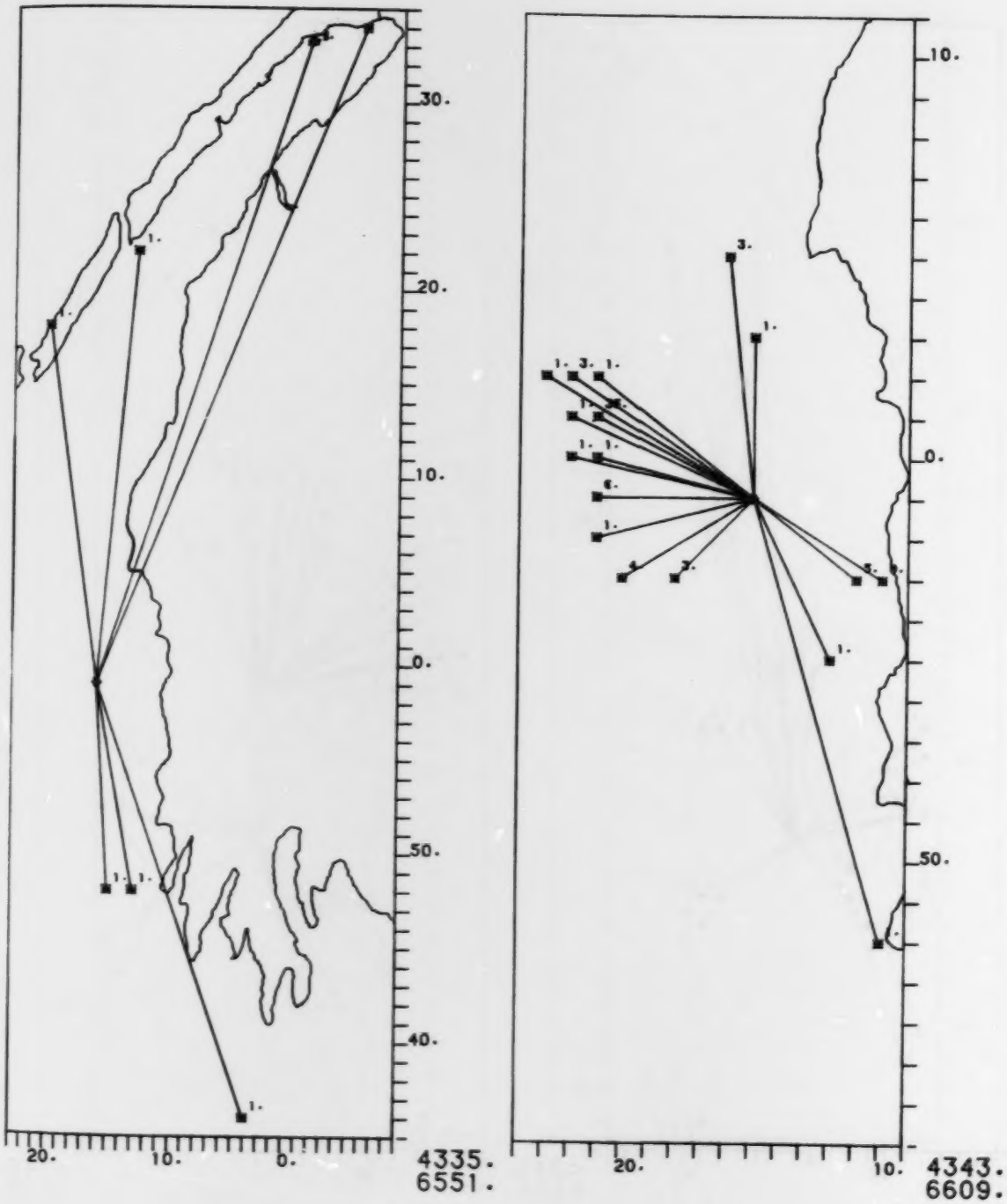
1946



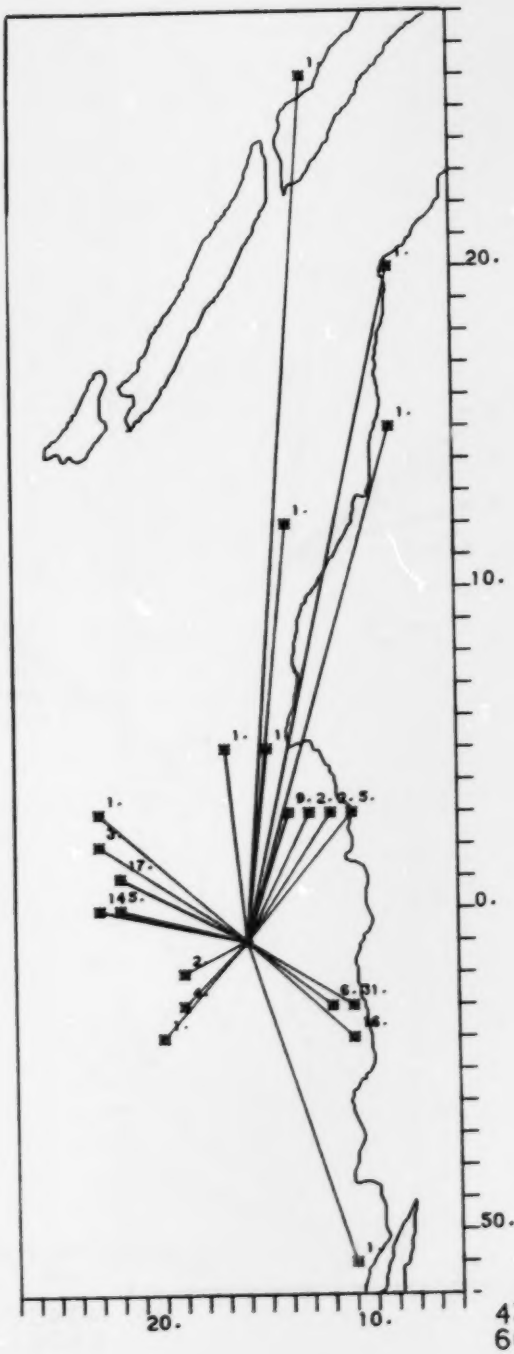
1947 **<18.5 km**



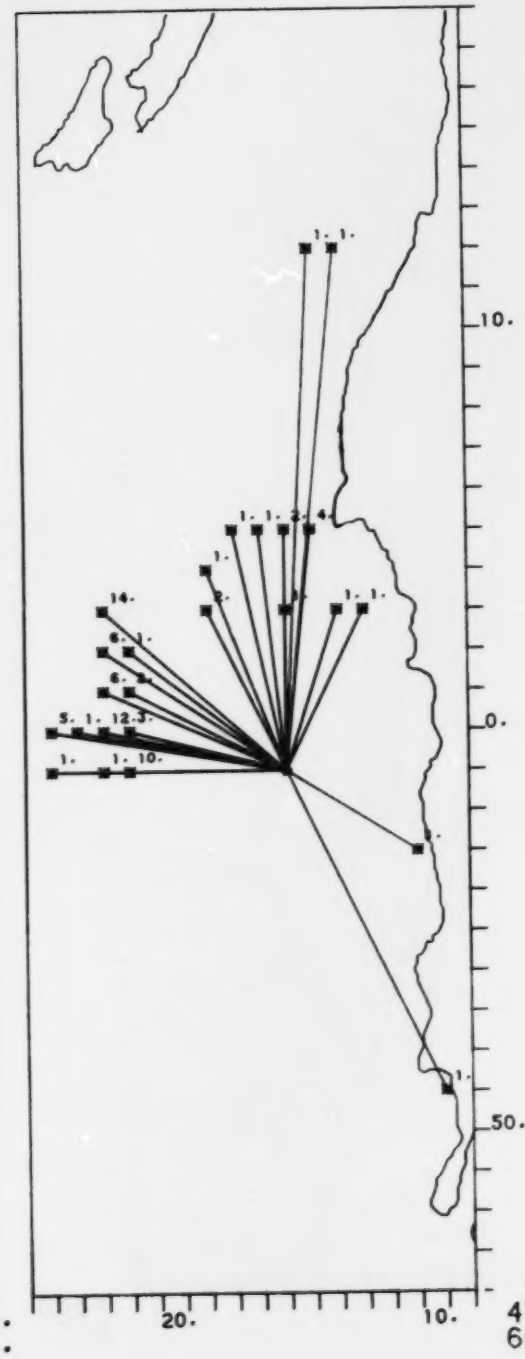
1947 ≥18.5 km 1948



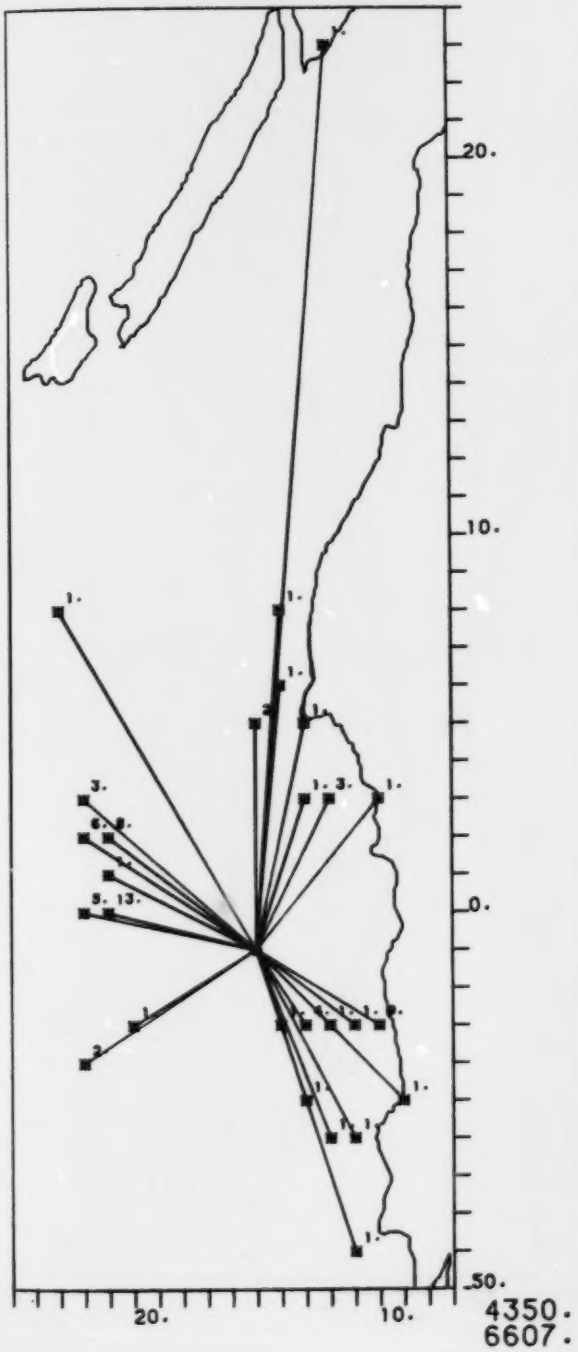
1949



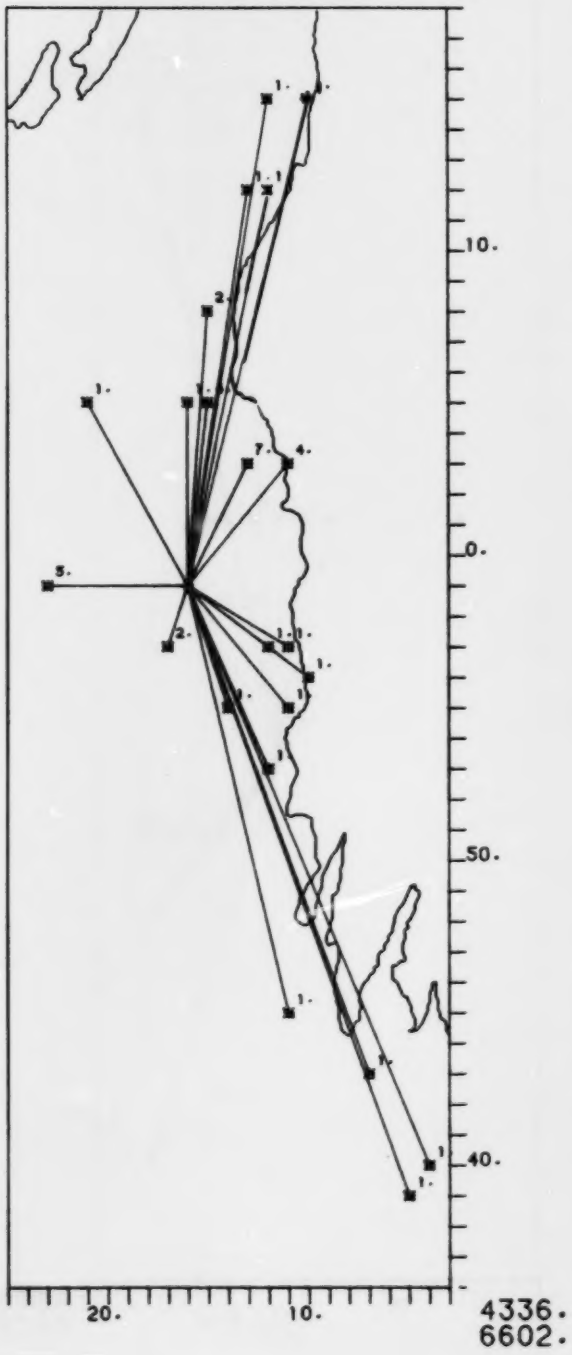
1950



1951



1952



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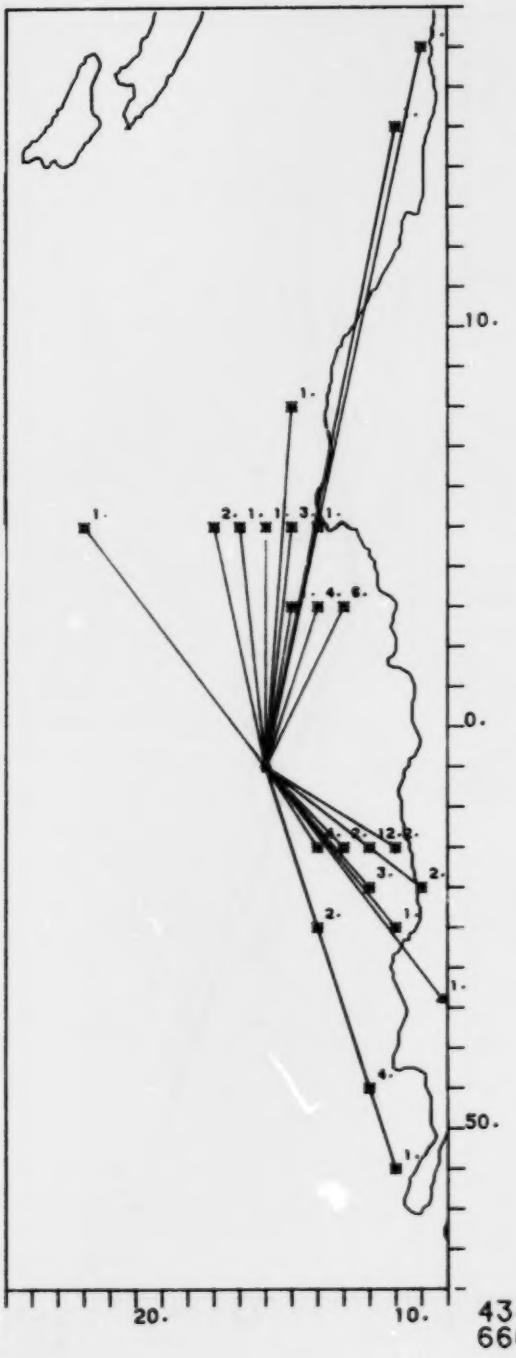
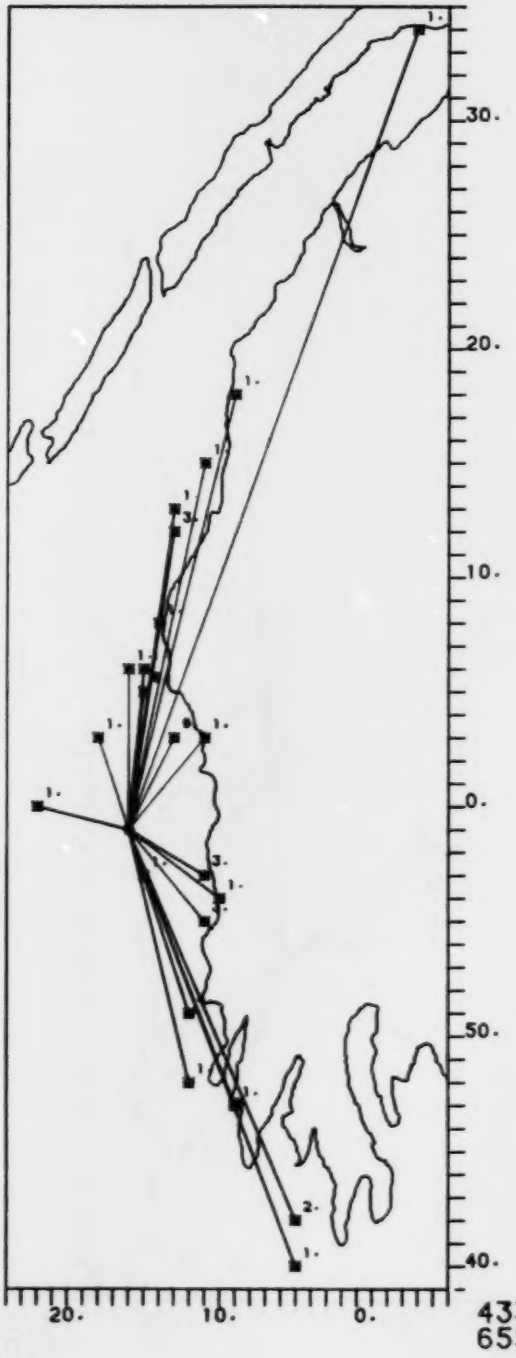
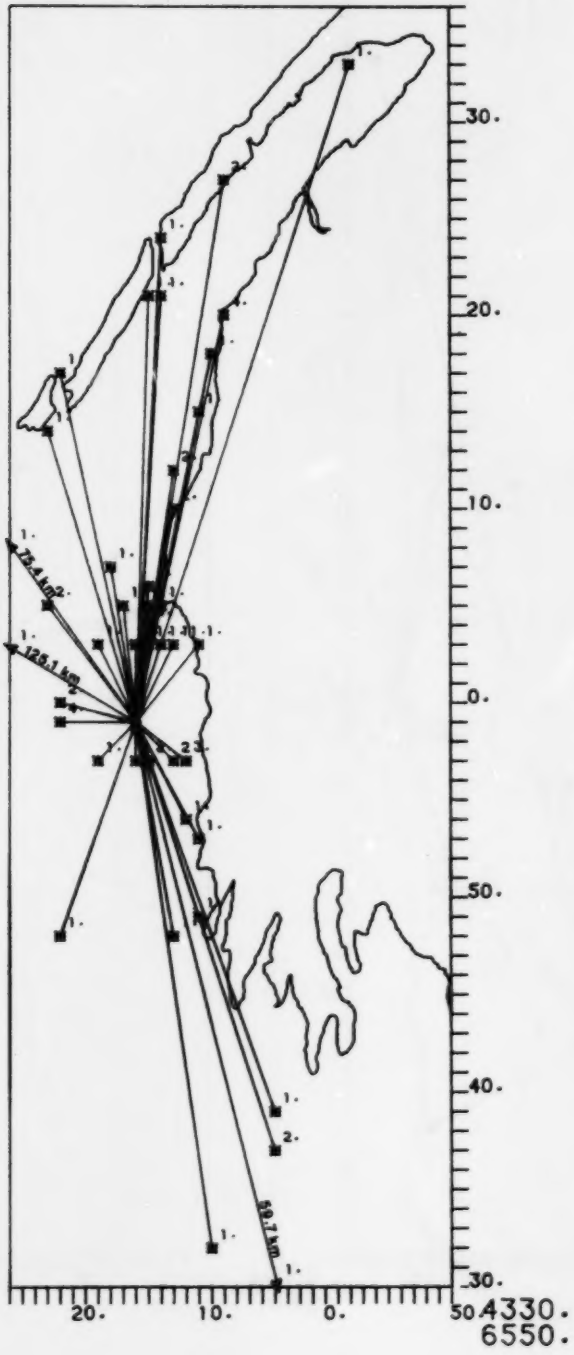


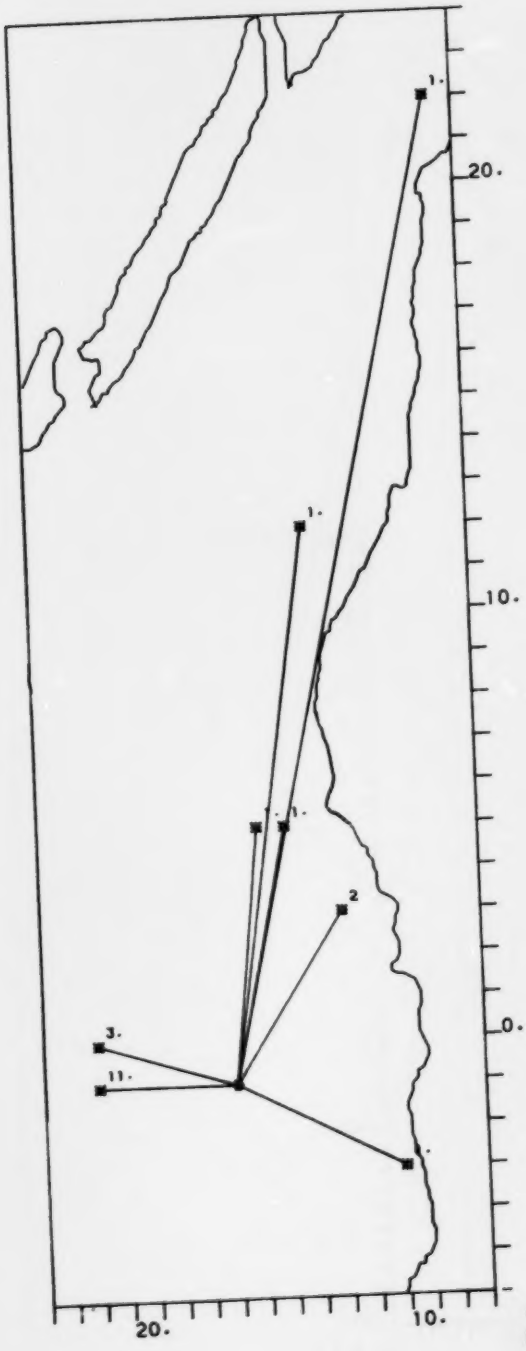
1954



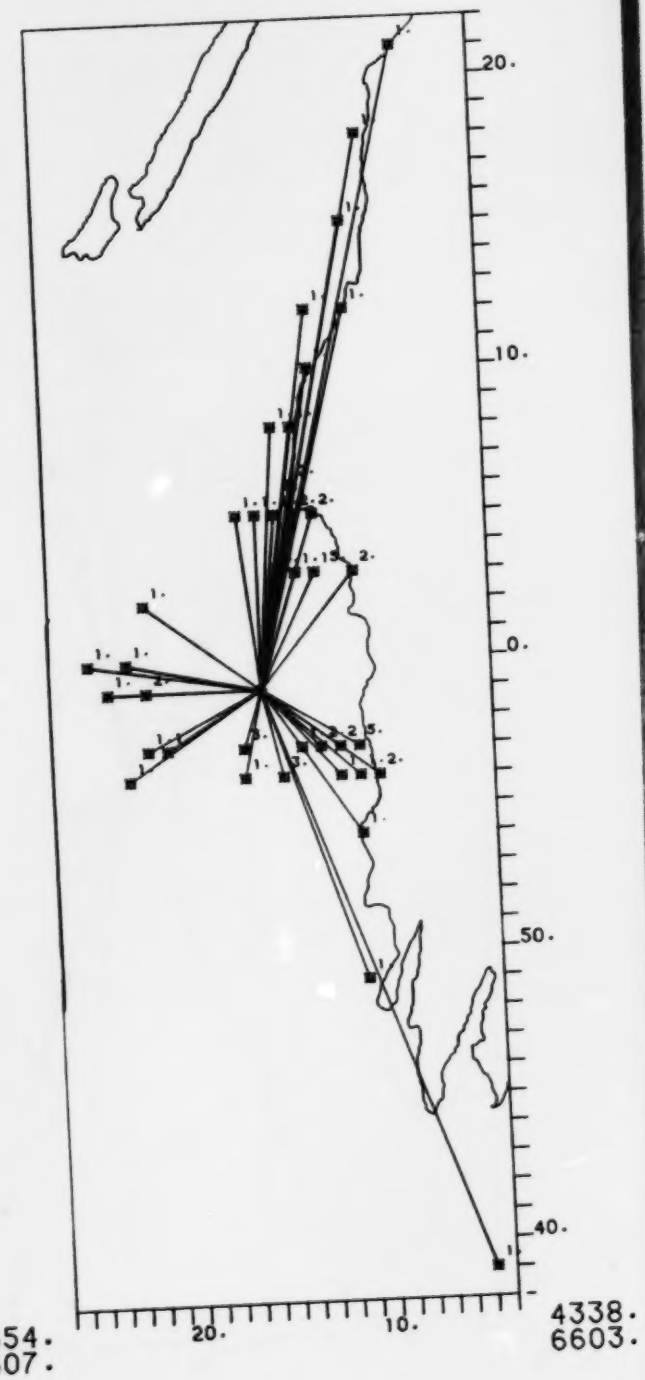
1955



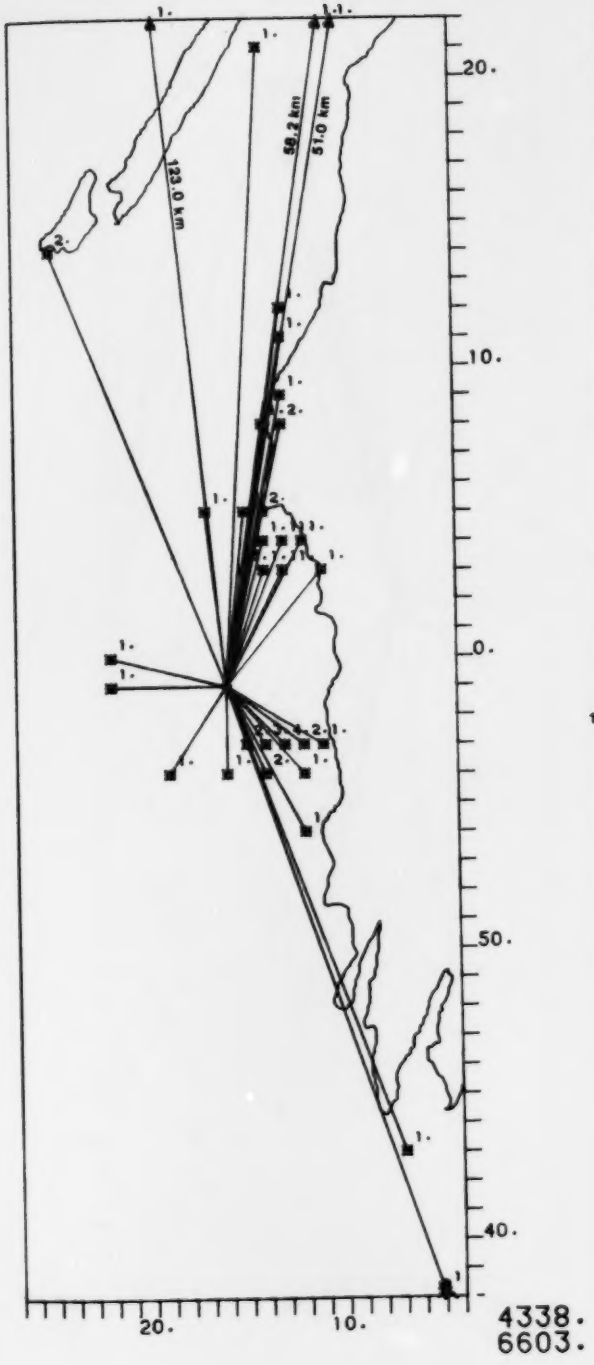
1956 MIGRATORY



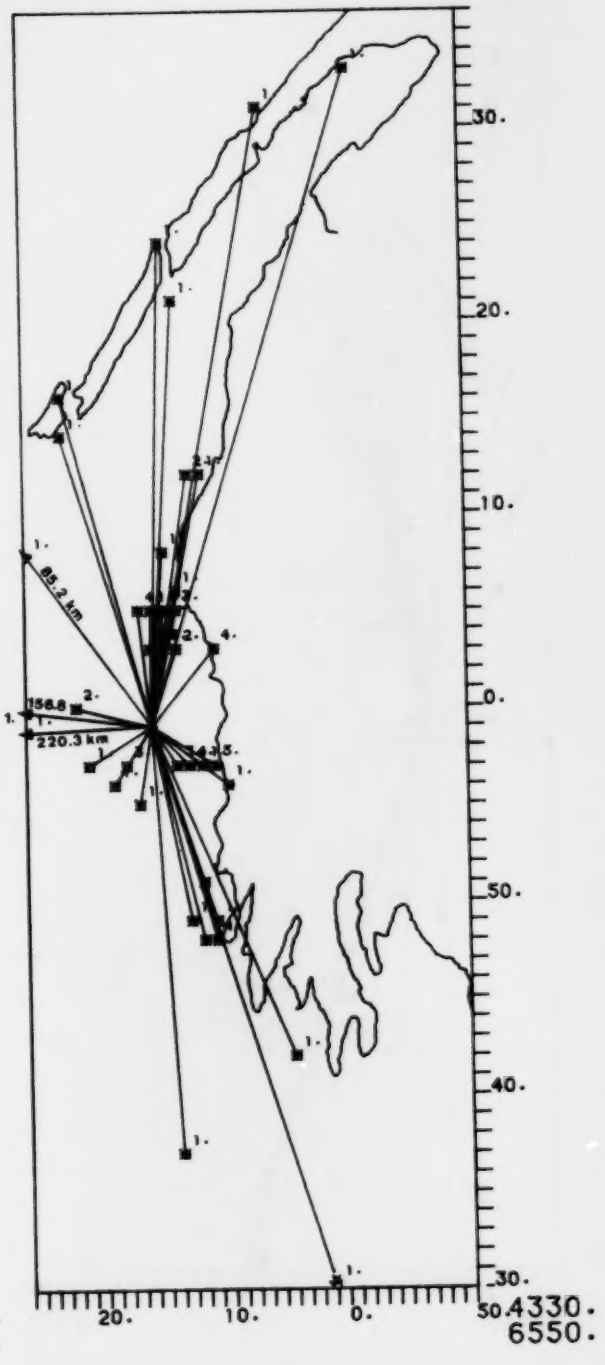
1956



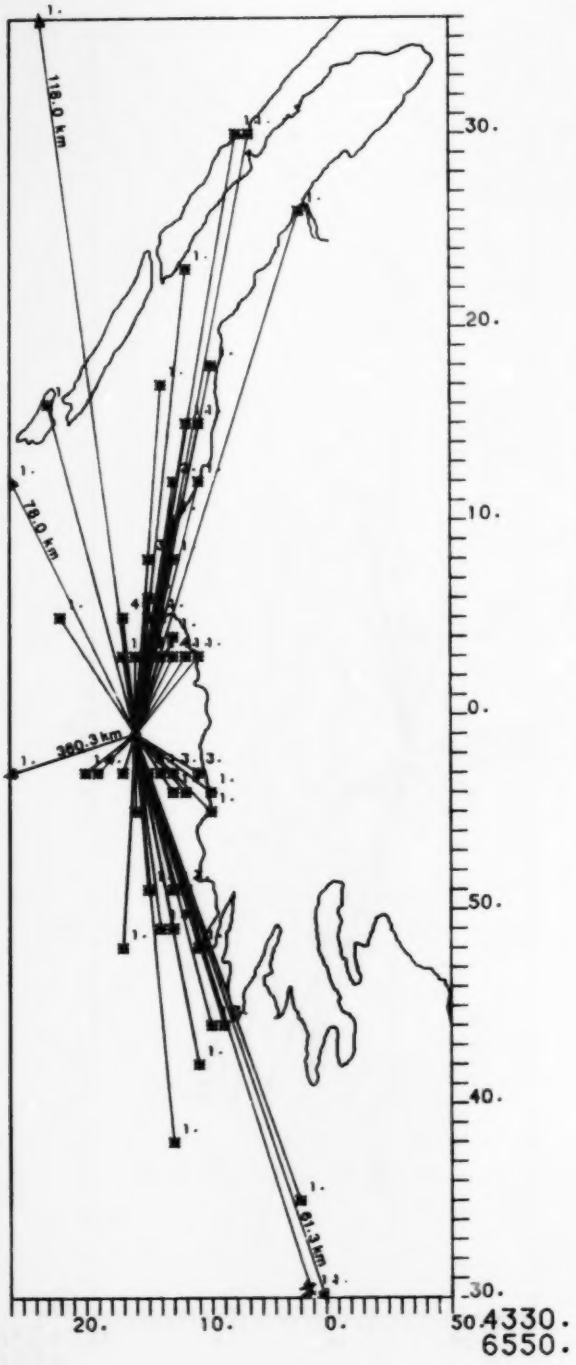
1957


123.0 km
59.2 km
51.0 km
20.
10.
0.
50.
40.
20.
10.
4338.
6603.

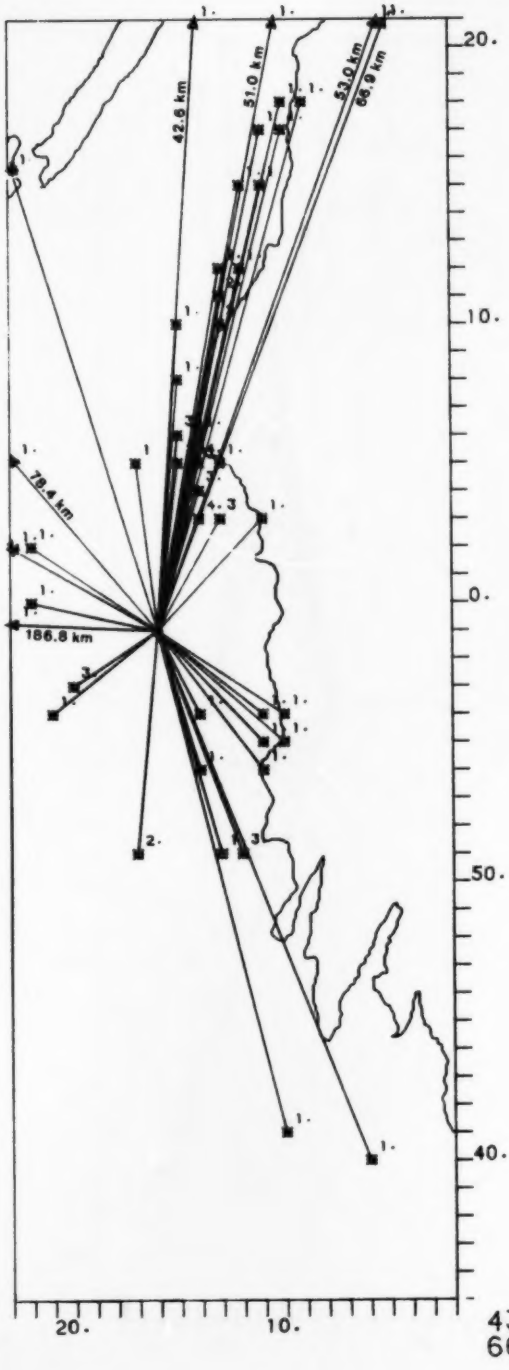
1958


88.2 km
156.8
220.3 km
30.
20.
10.
0.
50.
40.
30.
20.
10.
0.
50.
4330.
6550.

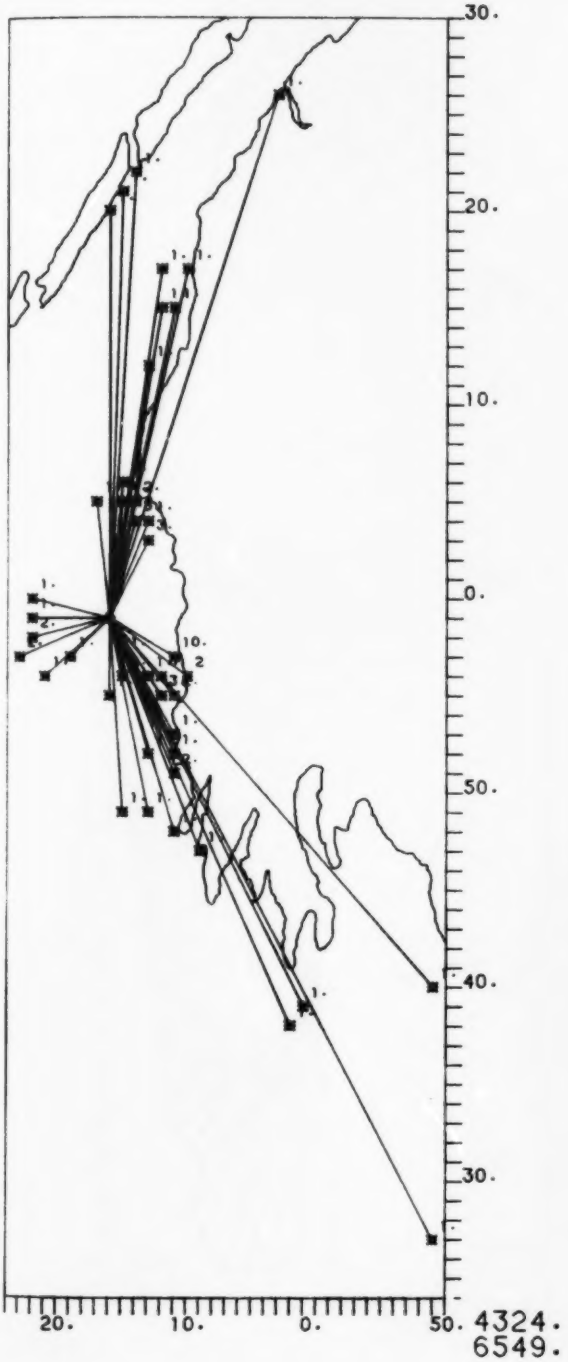
1959


118.9 km
78.9 km
380.3 km
81.3 km
30.
20.
10.
0.
50.
40.
20.
10.
0.
50.
4330.
6550.

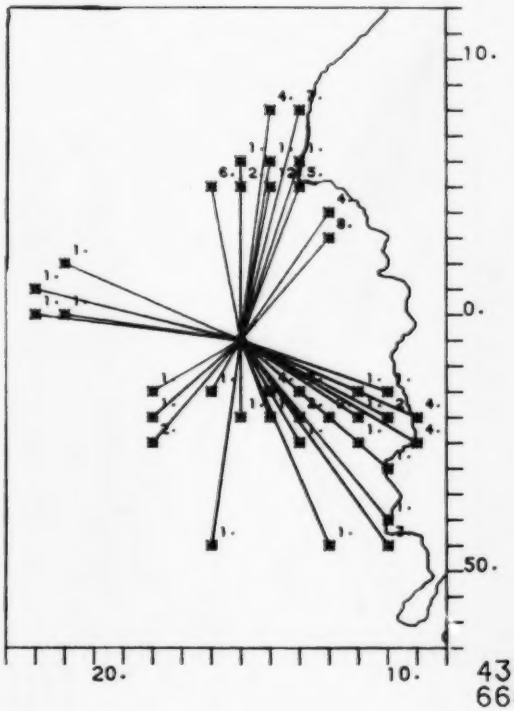
1960


42.6 km
51.0 km
53.0 km
66.9 km
78.4 km
186.8 km
20.
10.
0.
50.
40.
20.
10.
4335
6601

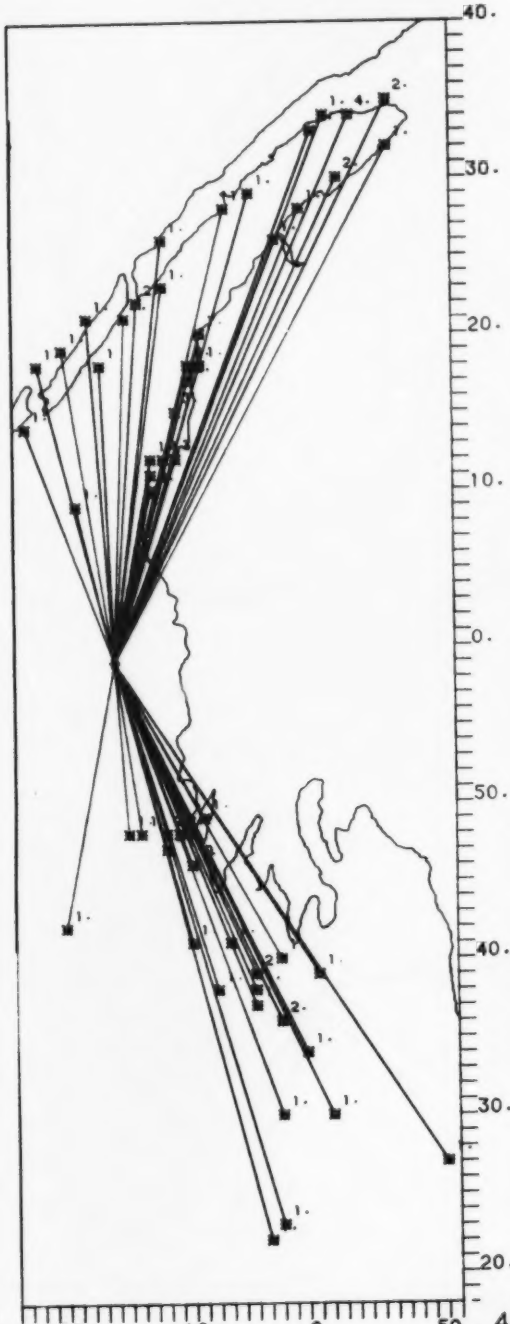
1961



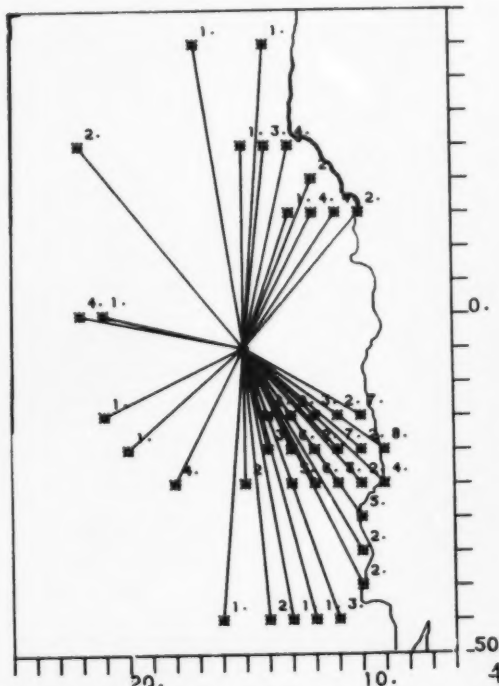
1962 <18.5 km



1962 ≥18.5 km

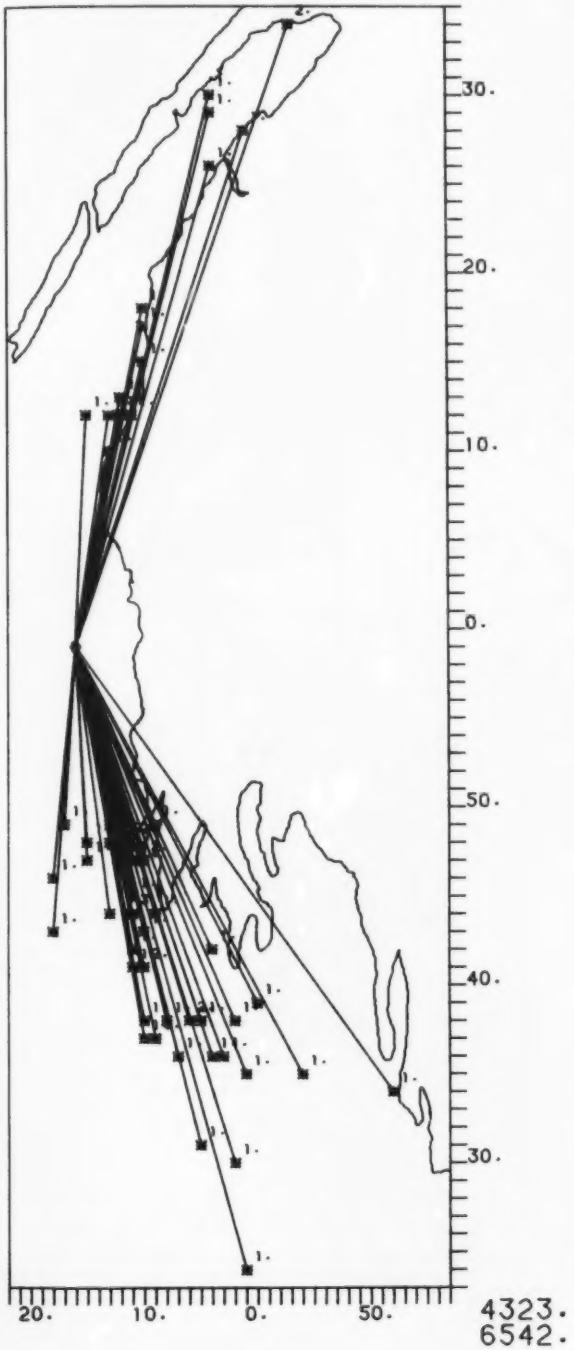


1963 <18.5 km



1963

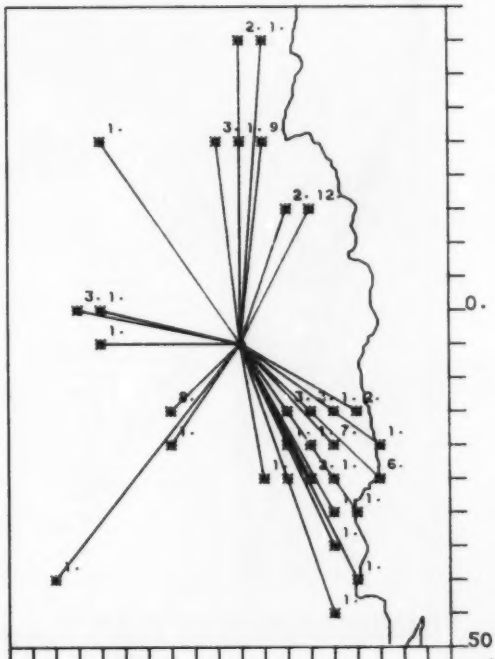
≥18.5 km



4323.
6542.

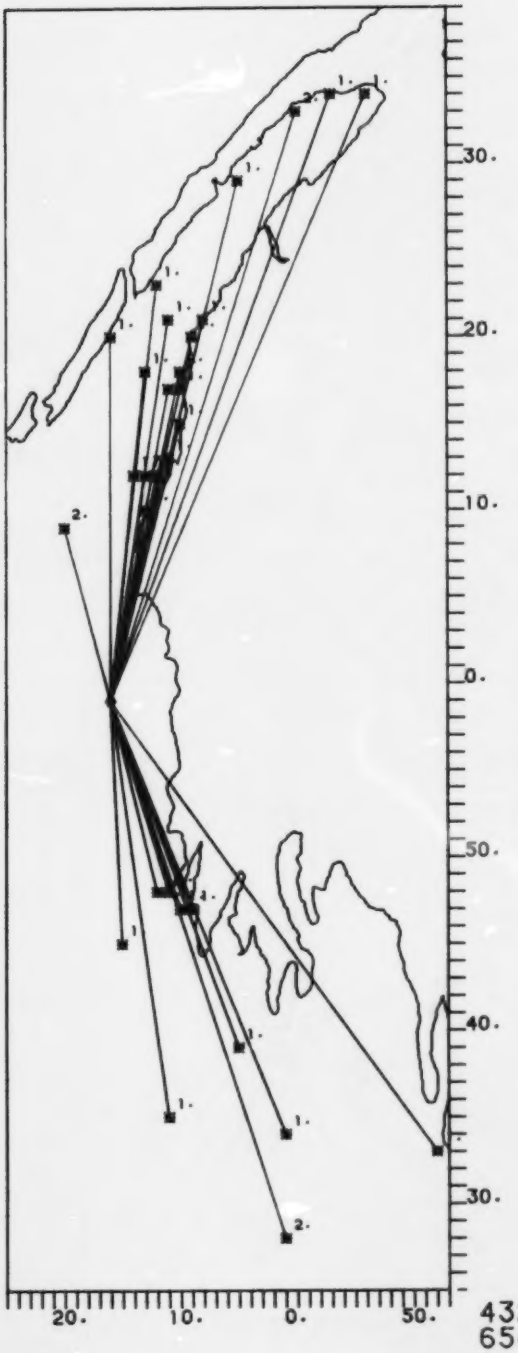
1964

<18.5 km

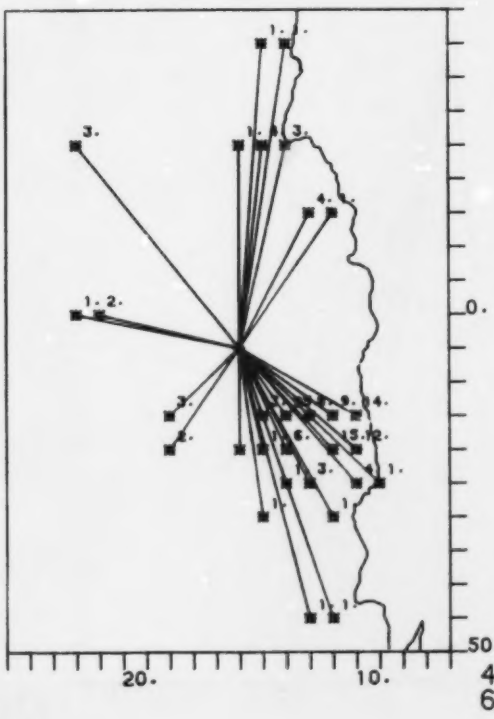


4350.
6606.

1964 ≥18.5 km

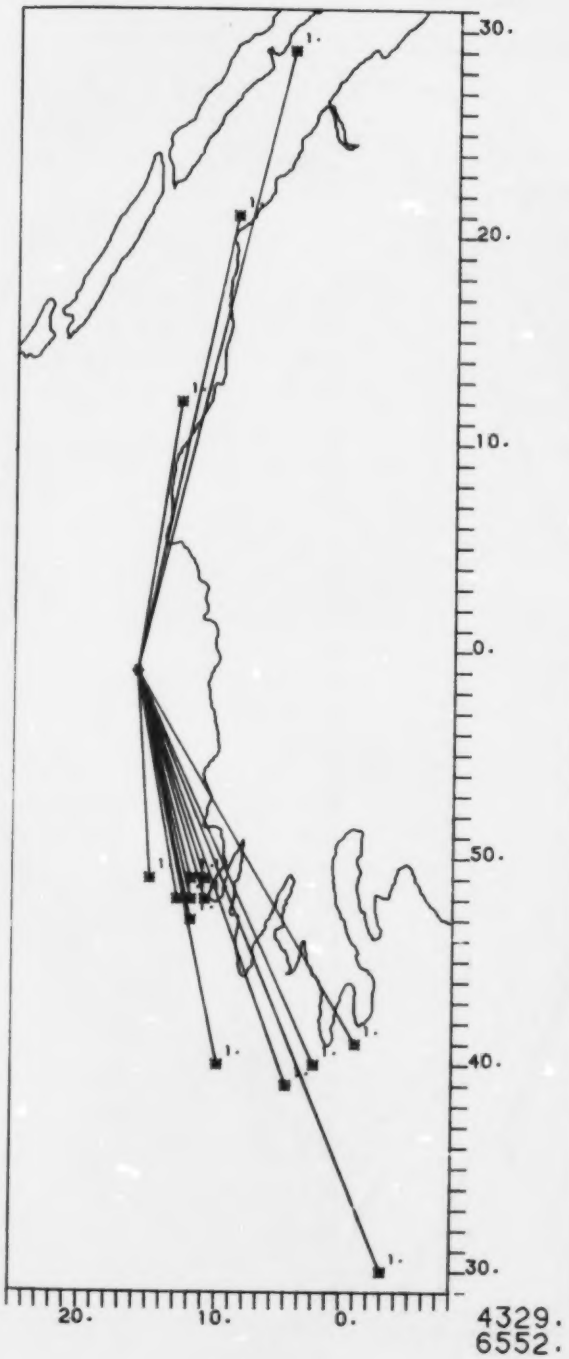


1965 <18.5 km



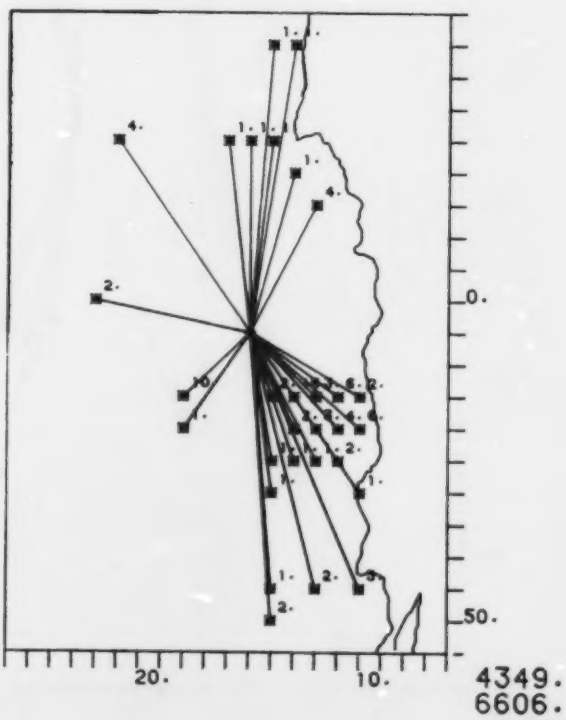
1965

≥18.5 km



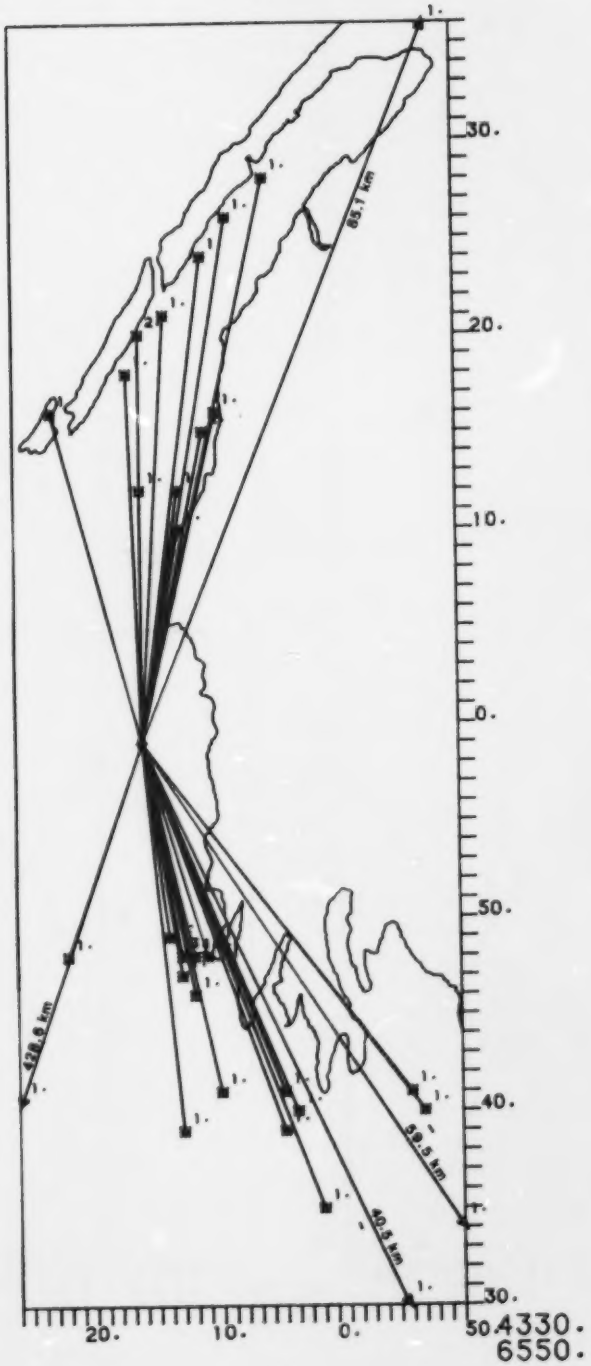
1966

<18.5 km

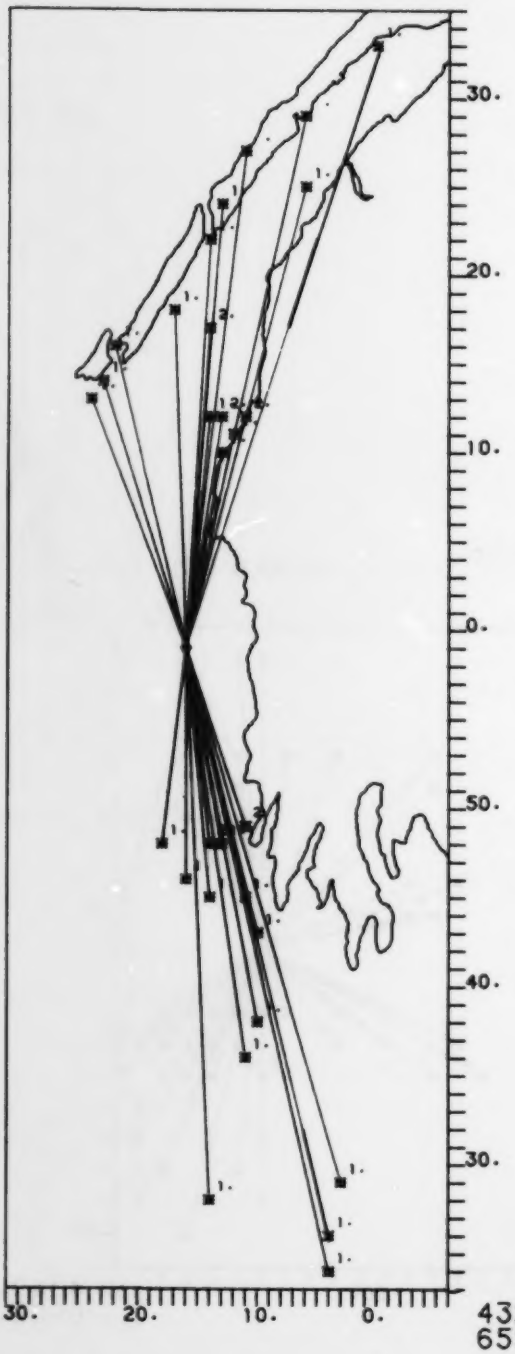


1966

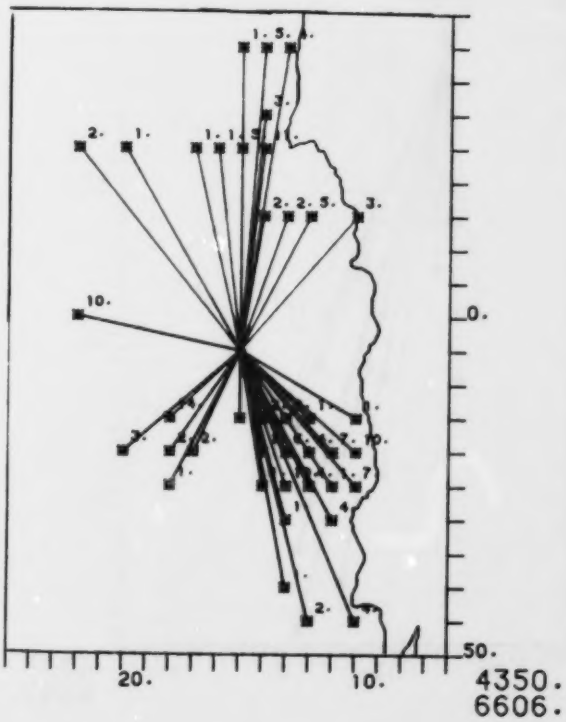
≥18.5 km



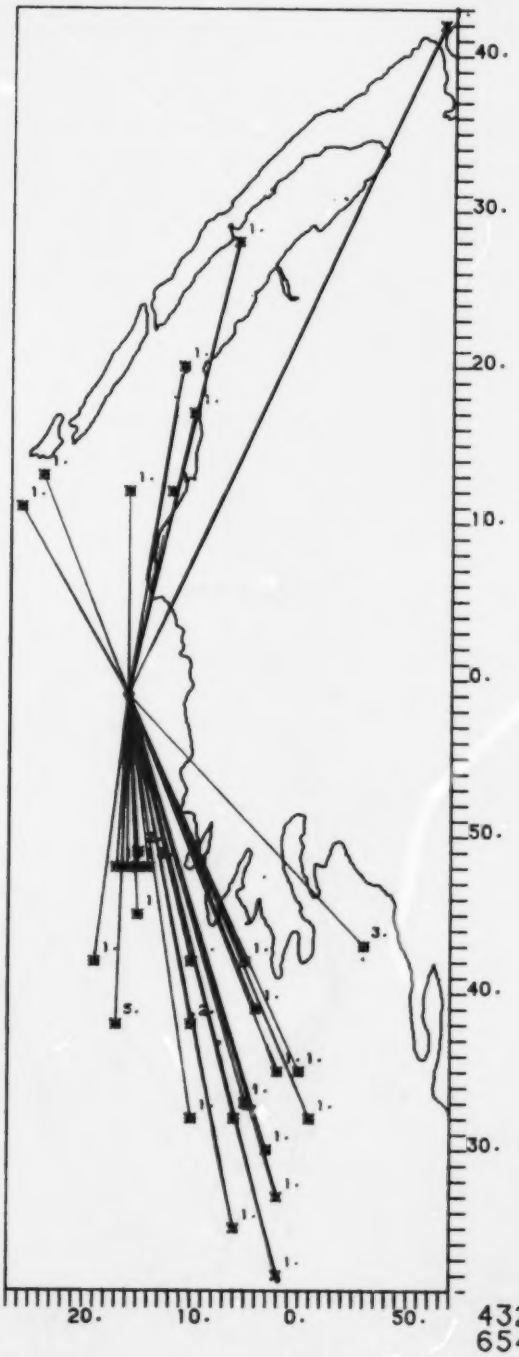
1967 ≥18.5 km



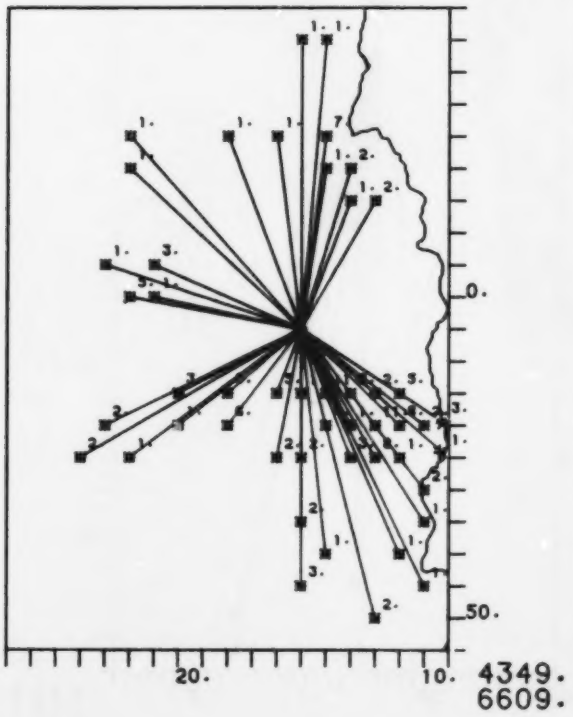
1967 <18.5 km



1968 ≥18.5 km

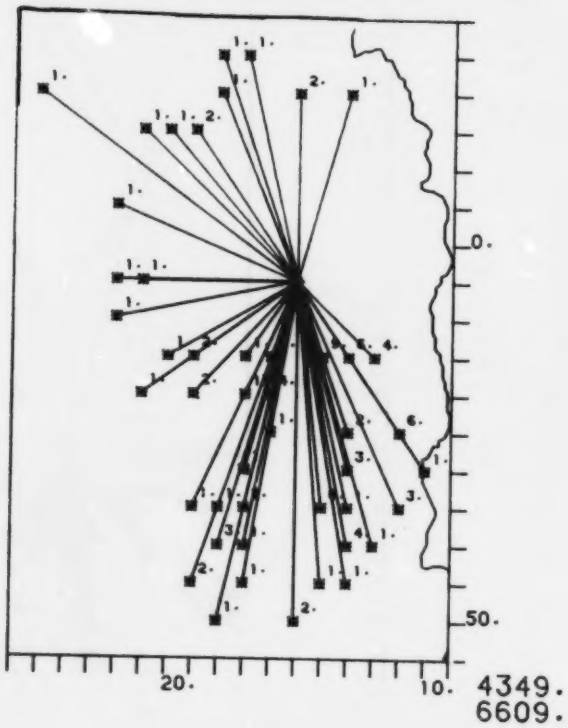


1968 <18.5 km

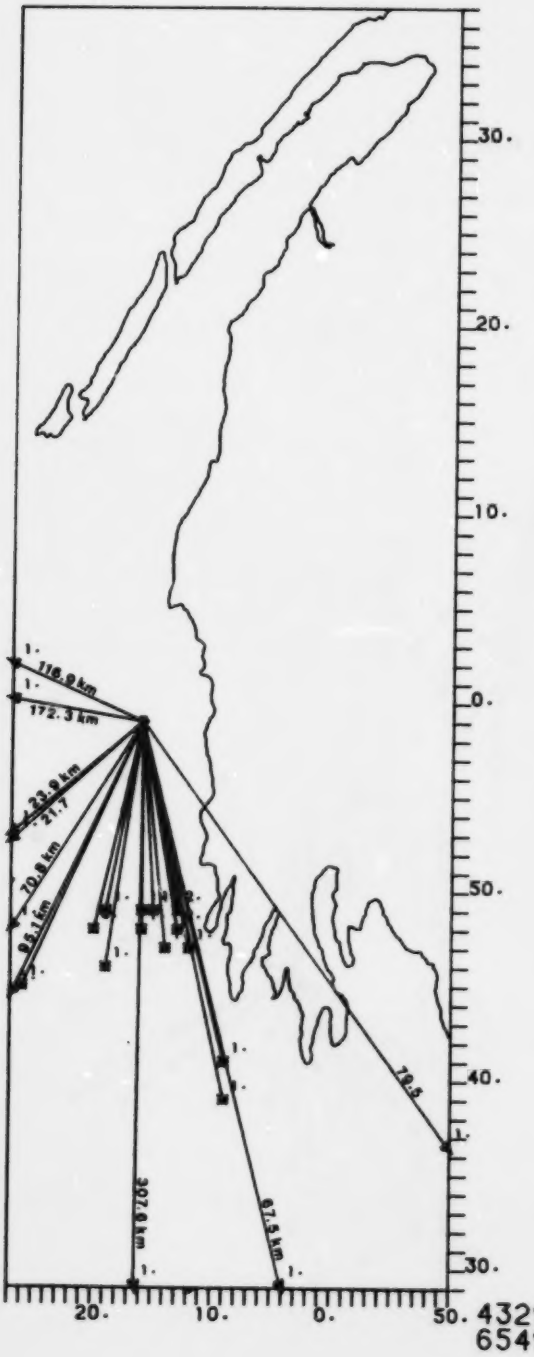


1978

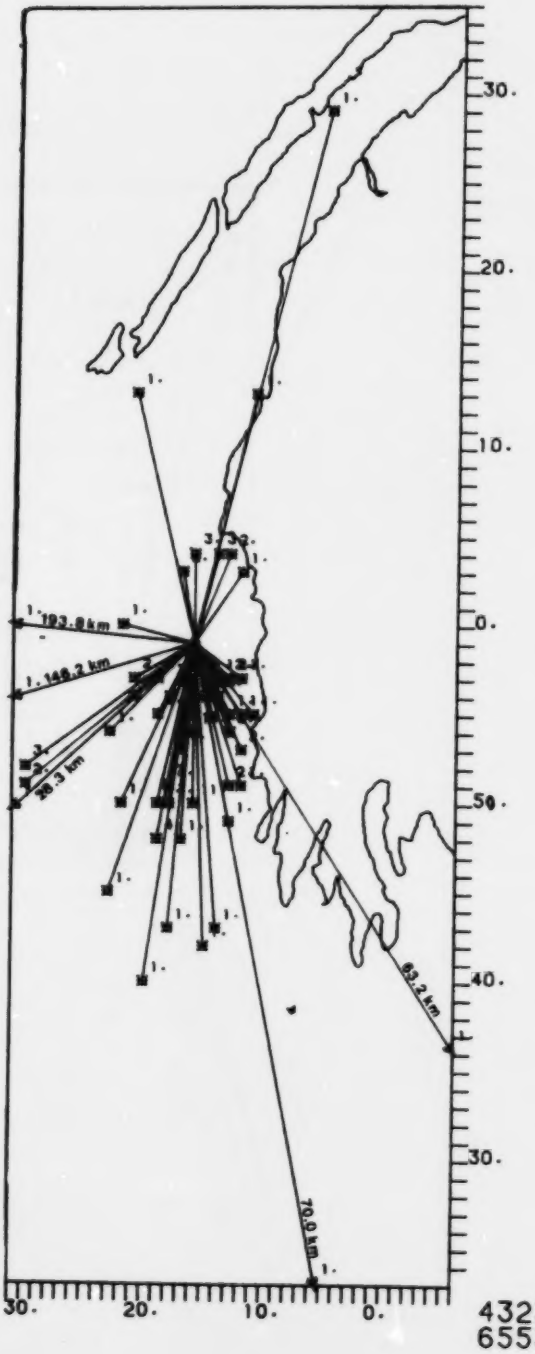
<18.5 km



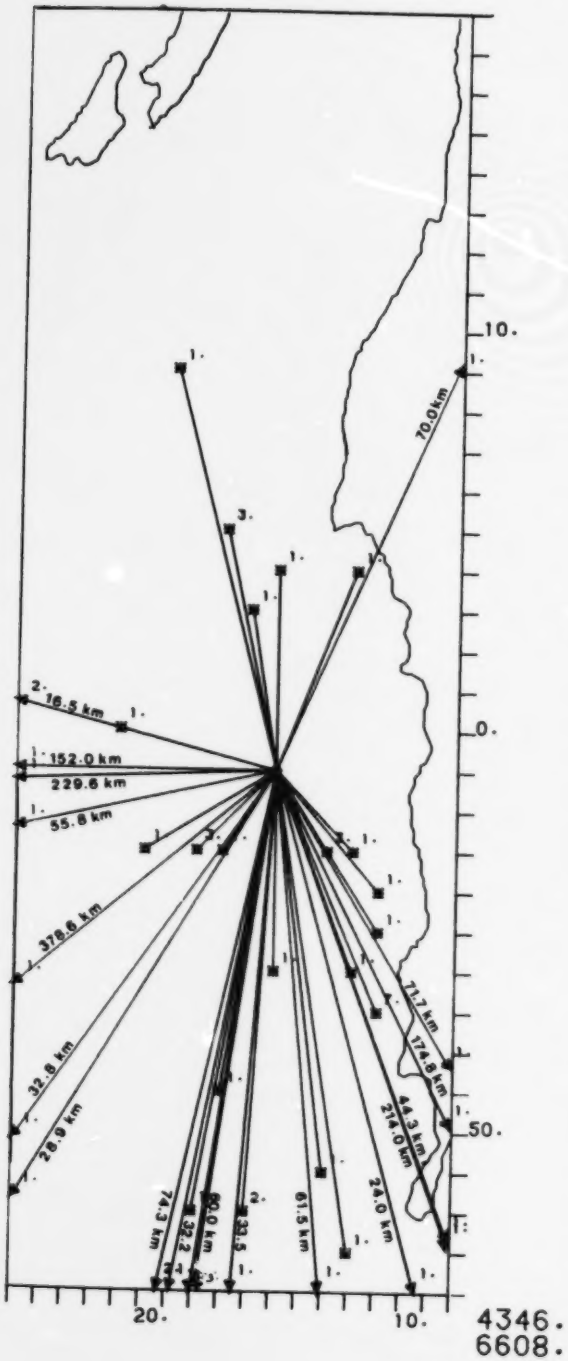
1978 ≥18.5 km



1979 FALL



1979 SPRING



1980